Comprehensive Statewide Transportation Model

Multimodal Investment Analysis Methodology Phase II
Final Report

Sponsored by
the Iowa Department of Transportation
CTRE Management Project 98-27

May 2001

CTRE
Center for Transportation
Research and Education

Iowa State University

Iowa Department
of Transportation

COMPREHENSIVE STATEWIDE TRANSPORTATION MODEL

MULTIMODAL INVESTMENT ANALYSIS METHODOLOGY PHASE II

FINAL REPORT

Principal Investigator
Clyde Kenneth Walter
Associate Professor of Transportation and Logistics
Iowa State University

Principal Contributor
Stephen J. Andrle
Director
Center for Transportation Research and Education

Project Manager
Tim Strauss

Graduate Assistants
Sujaya Rathi
Takehiro Misawa

Preparation of this report was financed in part
through funds provided by the Iowa Department of Transportation
through its research management agreement with
the Center for Transportation Research and Education,
CTRE Management Project 98-27.

Center for Transportation Research and Education
Iowa State University
ISU Research Park
2901 South Loop Drive, Suite 3100
Ames, Iowa 50010-8632
Telephone: 515-294-8103
Fax: 515-294-0467
http://www.ctre.iastate.edu

MAY 2001

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EXECUTIVE SUMMARY

A comprehensive model of statewide transportation flows that is sensitive to the quality and capacity of the transportation network can be a valuable tool for programming investments in highways, airports, and intermodal transfer facilities. However, most planning models were developed to address the needs of a single mode and do not incorporate the feedback effects on the larger economy resulting from these investments.

Phase I of this project outlined the elements of a conceptual model for statewide transportation flows. Issues addressed in Phase I included transportation demand forecasting methodologies, modal split and network assignment procedures, social welfare impact measurement and distribution, economic feedback analysis, and database requirements and structure.

The purposes of this report (Phase II of the project) are to specify in mathematical form the individual modules of the conceptual model developed in Phase I, to identify and evaluate sources of data for the model set, and to develop the transport networks necessary to support the models.

The overall process of the proposed comprehensive model incorporates five steps:

1. An economic forecasting model (REMI model) estimates supply and demand for major commodity types, population, and employment. This model estimates the economic feedback from infrastructure investment.
2. Three submodels developed in this project allocate passenger and commodity flows in Iowa to the available transport modes—car, truck, rail, and air. The three submodels are (a) passenger travel, (b) transport of agricultural products, and (c) manufactured (nonagricultural) goods transport.

3. The results of the submodels are combined to estimate transport demand by mode.
4. The resultant demand estimates can be compared to system capacity in order to guide future infrastructure investments.
5. Alternative investment strategies can be tested for their effects on the regional economy.

Significant progress was made toward a functioning comprehensive statewide model. Networks were developed in a geographic information system software package. Mathematical model structures are produced for passenger and freight flows. Data sources are identified. Linkage of these components to a regional econometric model is described. This report is a resource document that can guide the implementation of a statewide travel model for Iowa.

1 INTRODUCTION

The conceptual comprehensive transport demand model, as described in the Phase I report (*1*), can address transportation issues and problems on a regional or statewide scale. The model differs from the traditional approaches to transport demand modeling in that it incorporates both passenger and freight transport in one model system. This conceptual model, which incorporates the REMI economic impact analysis model, paves the way for more rigorous mathematical forms of the submodels, potentially leading to more realistic forecasting.

1.1 The Comprehensive Model Versus Traditional Models

Traditional transportation planning models were designed for use in urbanized areas to address problems and service needs associated with passenger travel either by private vehicle or public transit. Traditional models include information on levels of activity, such as population, employment, personal income, and trade flows, as exogenous factors used to estimate trip generation and distribution. Only a few states have developed operational statewide transportation models, and those that do exist include only the highway portion of their surface transportation system. Also, those states that have tried to adapt urban transportation models for use in statewide planning have generally encountered problems in simulating freight movements. The reason for this problem is that the factors influencing passenger and freight transportation service demands are fundamentally different. Thus, the comprehensive models have tried to integrate passenger and freight transport demand by taking into account the different sets of factors that influence passenger and freight demand.

Conventional transportation models do not take into consideration the feedback effects on the economy provided by transportation system improvements. Although such models reflect the impact of diverted trips resulting from transportation system improvements, they generally do not consider future travel impacts on the affected area's economy from system changes. Also, most existing transportation models lack the capability to identify the distribution of impacts associated with transportation system improvements on different population and business groups.

Thus, the comprehensive model developed here internalizes factors that are omitted from traditional transportation models, permitting dynamic analysis of the transport demand. This model can also analyze transportation investment decisions. The process is shown in Figure 1.1 and outlined below.

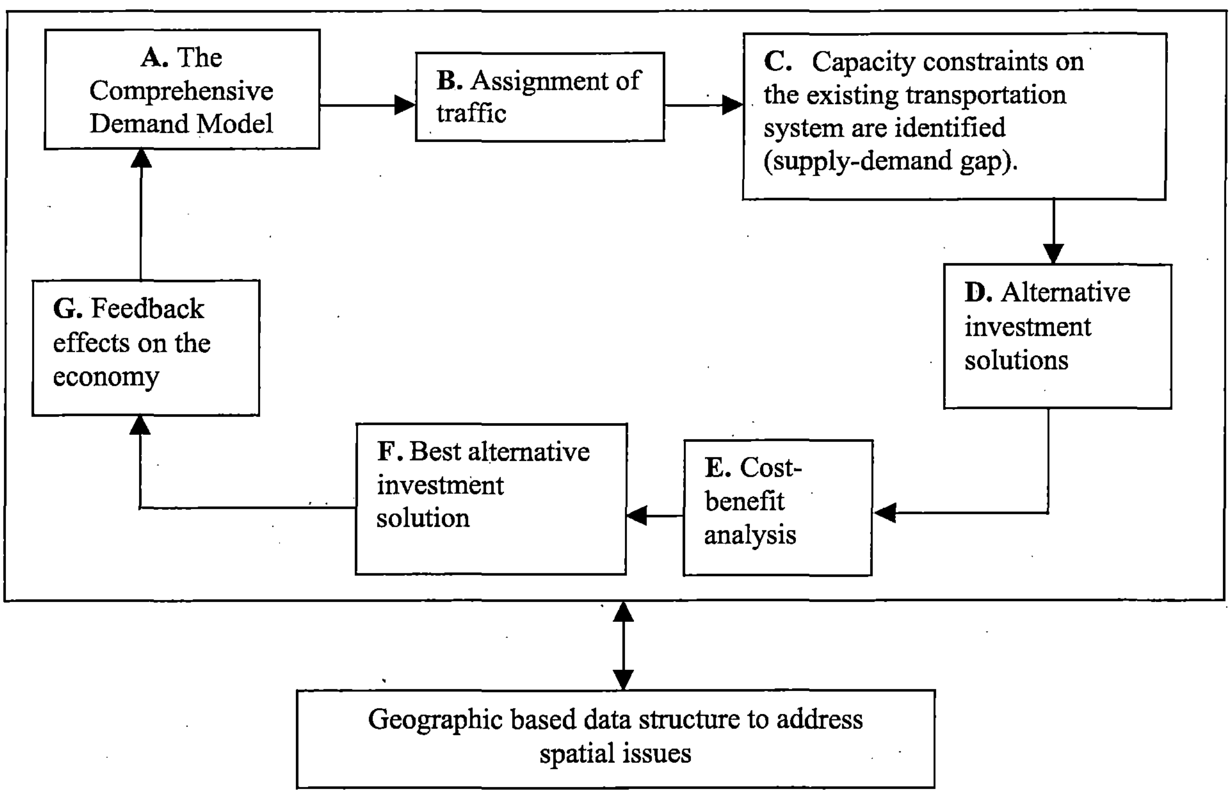


FIGURE 1.1 The Role of the Comprehensive Model in Transportation Investment Analysis

A. The output of the demand model is an estimation of the demand for all modes, generated by passenger and freight demand.

B. Next, trip assignment of traffic for the different modes to specific routes is accomplished.

C. The capacity constraints on the existing transportation and logistics system are identified at this time. The magnitude of the system deficiencies can be quantified at this stage.

D. There may be more than one alternative to address the transportation system requirements.

E. In order to arrive at the best investment decision, the cost/benefit analysis of all the feasible alternatives needs to be performed.

F. The cost/benefit analysis of the various alternatives for improving the capacity of the system identifies the best solution.

G. The alternatives will have different impacts on the economy of the area under study; feedback effects from the economy to the transportation and logistical system may be expected.

1.2 The Components of the Comprehensive Model

The comprehensive model has three components; these components are presented in detail in this report:

1. **The regional economic model or the feedback component (REMI model)** discussed in Chapter 2.
2. **The intercity passenger modal choice demand component** is described in Chapter 3. The chapter describes how passenger travel demand is estimated through established gravity models. The purpose for travel is related to underlying

socioeconomic factors, such as household income, motor vehicle ownership, square-footage of retail shopping area, and number of jobs.

3. **The intercity freight modal choice demand (agricultural and manufactured goods) component** is discussed in Chapter 4. Added emphasis was placed on freight transportation by the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, recognizing the need to improve efficiency in the movement of commodities. The demands freight transportation services are treated differently for agricultural products and for manufactured goods.

The whole system is presented schematically in Figure 1.2, and the working steps of the model are described below.

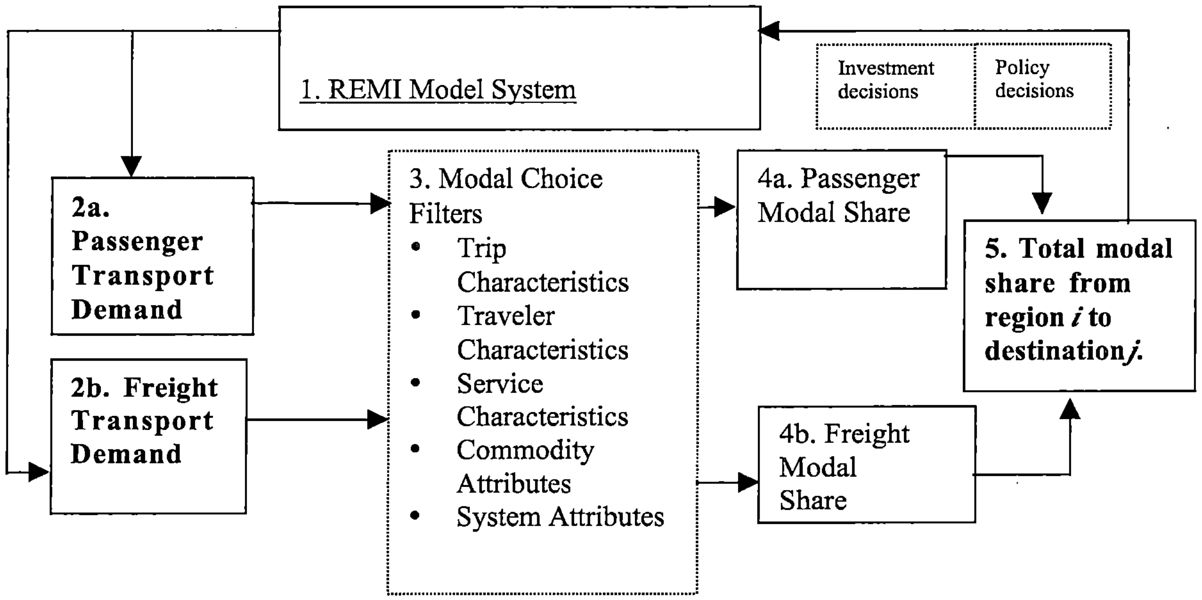


FIGURE 1.2 The Comprehensive Modal Choice Demand Model

1. The REMI model estimates and forecasts the variables of the system, such as population, employment by industry. These estimates are exogenous variables to the passenger and freight modal choice submodels.
2. The submodels determine the demand for each mode for passengers (a) or for a particular commodity (b), from origin *i* to destination *j*.
3. The demand for a particular mode is determined.
4. The total demand (passenger [a] and freight [b] combined) can be determined.
5. The capacity of the system (highway, air, water, pipelines, or rail) when compared to the demand for that particular infrastructure will affect policy decisions at national, regional, and state levels. The investment decision that will be needed to fill in the supply-demand gap will affect the economic system and will again influence the economic activity of the region. This will be reflected in the REMI model system. Thus the dynamics of the economic system will be captured in the comprehensive modal choice demand model system, while estimating the total demand for a particular mode from region *i* to region *j*.

1.3 Rationale for Model Structure

Conceptually, the comprehensive model incorporates the following principles:

1. The demand for transportation is a derived demand. The quantity of travel or shipping is a response to levels of economic activity.
2. The model does not assume equilibrium. It accounts for dynamic changes in population, economic activity, transport demands, transport infrastructure changes, and environmental and social impacts.

The framework of the model, as described in the Phase I report of the project, was developed following a review of the literature on transportation demand forecasting and modeling, regional economic models, and data needs and sources. The purpose of the literature review was to highlight the features of existing models that may be incorporated into the comprehensive transport demand model. The review also provided an understanding of deficiencies in the existing models and current transportation planning practices.

The model to be constructed incorporates many elements of the traditional urban transportation modeling process, but it differs in the following respects:

1. Traditional urban transportation models focus on passenger transportation only, whereas this model addresses both passenger and freight transportation demand.
2. The model is demand driven, meaning no *a priori* assumptions are made regarding the forecasting of a particular transport system demand. The economic component of the model forecasts economic variables within the system, which are then used by the passenger and freight submodels for demand estimation. Traditional transportation models include information on levels of economic activity, such as population, employment, personal income, and trade flows, as exogenous factors used to estimate trip productions and attractions.
3. Trip generation and mode choice behavior has been disaggregated to capture more accurately the unique transportation service demands of intercity passenger, natural resource and agricultural commodity, and manufactured goods traffic.
4. The mode choice analysis incorporates a series of filters associated with trip purpose and population characteristics for passenger service demands, and product and market attributes for freight service demands.

5. Economic feedback effects are generally ignored. This model incorporates the economic feedback effects, through the REMI model on the transport demand system, in contrast to most traditional transportation models.

Thus, this model internalizes many factors that are omitted from traditional models and so permits the dynamic analysis of transport system demand.

1.4 The Unit of Economic Activity on Which the Model Is Based

The economic unit used in the model is counties for Iowa and Bureau of Economic Analysis (BEA) regions outside Iowa. Use of the county as the basic economic unit is consistent with two other state models. The Wisconsin freight model and the Indiana freight model also use a county-level traffic analysis zone (TAZ) structure (*2*). This appears to be the accepted level of geographical detail, especially for freight modeling, for two reasons. First, essential commodity flow information has been widely available only at the BEA region level of detail, which is too large a geographical area for meaningful use in a statewide model. Use of this involves only one step of disaggregation. In contrast, using smaller scale TAZs (e.g., at the Census tract or township level) typically involves additional disaggregation steps and additional layers of assumptions about the characteristics of the commodity flows. Second, a large amount of economic information is available (e.g., county business patterns) or will be soon available (e.g., the Reebie and Colograpy databases) at a county level for use as inputs to a statewide freight model. Though socioeconomic data are available for Census tracts, in order to be consistent with the TAZ structure, county-level TAZs for Iowa are used for both passenger and freight models.

2 REGIONAL ECONOMIC FORECASTING MODEL (REMI MODEL)

The purpose of modeling statewide transportation demand is to guide the allocation of infrastructure resources and estimate the resultant effect on the state's economy. In order to do this, the ouputs of the transportation models must be entered into a regional economic forecasting and simulation model. It is easiest to follow the development of the model chain by first understanding the regional economical context. The submodels estimating passenger travel, agricultural freight, and manufactured freight are described in succeeding chapters.

Regional Economic Models, Inc. (REMI), founded in 1980, develops forecasting models that reveal the economic and demographic impact that public policy initiatives or external events may have on a local or regional economy and population. REMI's 53-sector Economic-Demographic Forecasting and Simulation Model (EDFS-53) is designed with the objective of improving the quality of research-based decision-making in the public and private sectors. It is calibrated to many subnational areas for forecasting and policy analysis by government agencies, consulting firms, nonprofit organizations, universities, and public utilities throughout the United States. Simulations with the model are used to estimate the economic and demographic effects on the aggregate regional economy by economic development programs, transportation policies, infrastructure investments, environmental improvements, energy and natural resource conservation programs, state and local tax changes, and other policy initiatives.

The structure of the REMI model (see Figure 2.1) incorporates inter-industry transactions and an endogenous final demand output. In addition, the model includes substitution among factors of production in response to changes in relative factor costs, migration in response to changes in expected income, wage responses to changes in labor market conditions, and changes in the share of local and export markets in response to changes in regional profitability and production costs (3). The essence of the REMI model is the extent that theoretical structural restrictions are used instead of individual econometric estimates based on single time-series observations for each region. The explicit structure of the model facilitates the use of policy variables that represent a wide range of policy options and the tracking of the policy effects on all the variables in the model. The inclusion of price responsive product and factor demands and supplies gives the REMI model much in common with Computable General Equilibrium (CGE) models. CGE models have been widely used in economic development, public finance, and international trade and have been more recently applied in regional settings.

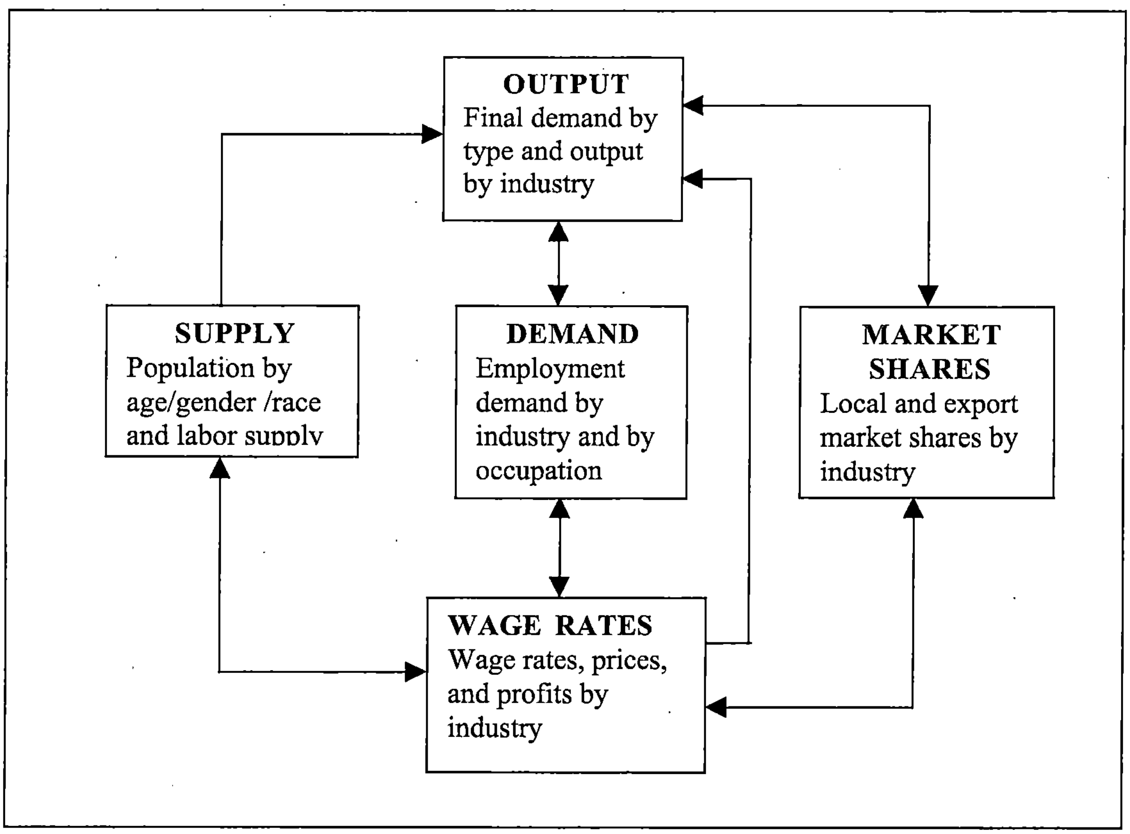


FIGURE 2.1 Linkages Among the Major Parts of the REMI Model
Source: http://www.remi.com/html/closeup.html (3).

REMI's EDFS models have three sizes: the EDFS-53 has two-digit industry detail; the EDFS-14 has one-digit industry detail; and the EDFS-172 has three-digit detail for forecasts and simulations and two-digit detail for historical years. Additional products that can be added to an

EDFS model include a quarterly model, a detailed occupational matrix, and a 526-sector input-output model. In addition to having a single region U.S. model available, REMI also builds multi-region U.S. models that can be configured by grouping states and counties together into regions that cover the entire United States.

A REMI model accomplishes two things: it forecasts the future of a regional economy, and it forecasts the effects on that same economy when the user implements a change. The first forecast is called a control forecast. The second, which incorporates the policy changes, is called the alternative forecast or the simulation. The difference between the two represents the effect of the policy. For example, the effect of the improved roads is to reduce trucking costs. This reduction is accomplished in the model by increasing productivity in the trucking industry. In addition, productivity gains should also be introduced for industries that supply their own trucking. Transportation improvements that lead to reduced costs will reduce sales prices for regional industries. These reductions will be appropriately transmitted through the model. However, transportation cost reductions that directly reduce sales prices are different than other price reductions. They apply equally to competing imports to the extent that they reduce costs for imports. Therefore, the competitive response in the model for regional industries that increase local market shares when there are reductions in sales prices must be offset by appropriate reductions in the market share. The savings to automobile users is a reduction in cost (less commuting time) or increased benefits (safer travel) that will not be reflected by price indexes. Therefore, it should be treated as an amenity gain, and the amenity term in the migration equation should be adjusted by an amount that reflects the dollar value of non-pecuniary gains. This will increase the net number of migrants into the area and have ramifications in the labor market and the rest of the model and on the demand for passenger and freight transport.

The REMI model has seven features often unavailable in other microcomputer-based regional forecasting models that serve to enhance analysis of the type proposed (*4*):

1. REMI calibrates to local conditions and uses a large amount of local data, which is likely to improve its performance, especially under conditions of structural economic change.
2. REMI has a strong theoretical foundation.
3. REMI combines several analytical tools (including economic-base, input-output, and econometric models) to take advantage of each one's strengths.
4. REMI allows users to manipulate large number of inputs and generates forecasts for many output variables.
5. REMI allows user flexibility in analyzing the timing of economic impacts.
6. REMI accounts for business cycles.
7. REMI is proven to perform by large number of users under diverse conditions.

Incorporation of the REMI model system as the feedback component of the comprehensive modal choice demand models for freight and passenger transport will induce dynamic effects on the economy into the submodels of freight and passenger transport demand. This is essential for an accurate estimation of modal share. Thus, the introduction of the REMI model into the comprehensive model system allows the model to estimate its variables endogenously, unlike previous models of passenger and freight transport demand that treat demand variables as exogenous to models.

3 INTERCITY PASSENGER TRANSPORT COMPONENT

The conceptual model for intercity passenger demand is based on existing transport models reviewed in the Phase I report. This model incorporates the strengths of the existing transport models, sometimes in their original form and sometimes as modified models. The conceptual model integrates the various models (and submodels), incorporating the strengths of the existing models (*5*). The three steps of the conceptual passenger transportation model are (1) estimation of passenger traffic volume between cities, (2) distribution of traffic between modes, and (3) assignment of the transport volume for any mode to different routes of that mode between the two regions.

3.1 Trip Generation

The trip generation step (*2*) determines the total number of person trips that begin or end in a zone, usually over a 24-hour period. Trip totals for any zone are separately tabulated by trip purpose and whether they are productions or attractions. The following rules apply within most urban models:

- All home-based trips are produced at the home.
- All home-based trips are attracted to the end that is not the home.
- The networkwide total of productions must equal the total of attractions for each purpose.

Non-home-based trips are treated in a variety of ways. Many urban models generate a total amount of non-home-based trips, then split them evenly between productions and attractions. Trip productions and attractions are computed with separate empirical relationships. These relationships include the socioeconomic and demographic characteristics of zones but rarely include any travel characteristics of zones. But the trip generation equations for this model do include intrinsic characteristics of the zones.

The trip purposes that are considered in the model are work, business, and non-business travel. Non-business travel has been disaggregated to personal and recreation travel. (A detailed discussion of trip purposes is presented in the Phase I report.)

Trip production is most often calculated by multiplying a trip rate for a category of households by the number of households falling into that category. Categories are typically organized by number of persons in the household, number of automobiles in the household, or household income.

Trip attraction is most often calculated by a linear equation, where the dependent variables are demographic characteristics, such as retail employment, non-retail employment, and households.

The factors influencing trip generation are number taking a trip, trip-making propensity, accessibility, and pull factors; these are represented in Table 3.1 (and are discussed in detail in the Phase I report). These empirical relationships include the socioeconomic and demographic characteristics of zones but rarely include any travel characteristics of zones. The trip generation equations for this model do include intrinsic characteristics of the zones.

TABLE 3.1 Factors Influencing Trip Generation

Trip Purposes	Number of Trip Makers	Trip-Making Propensity	Accessibility	Pull Factors
Work travel (home-based)	Population size Population density	Income Household structure Family size Labor force participation Car ownership Occupation Percentage of non-workers	Access to jobs	Employment opportunities
Business travel	Land use mix of origin zone Employment in zone by occupation	Income Car ownership Type of business Business linkages	Intercity accessibility	Employment opportunities Roofed space for industrial, commercial and services
Non-business travel	Population density	Household size Car ownership Occupation Percentage non-workers	Access to shopping centers Access to leisure Access to friends	Shopping centers Intervening opportunities Other recreation opportunities

3.1.1 Intrazonal and Interzonal Trips

For statewide modeling, an important consideration is whether to generate all trips, including intrazonal trips, or to generate only the trips that are made between zones. Existing models tend to generate all trips, most likely because the available techniques for developing generation equations do not differentiate between intrazonal and interzonal trips. Instead, intrazonal travel times are adjusted within the trip distribution step to ascertain the correct number of intrazonal trips for individual zones.

3.1.2 Geographical Variations

There are also geographical variations in trip generation rates. Most important, small towns and rural areas tend to generate more trips per capita than urban areas. The time period of analysis must be considered when establishing trip generation rates. Urban models are mostly concerned with forecasting the amount of traffic on a typical weekday or within a single peak hour of a weekday. Statewide models have been designed to forecast the amount of travel on an average day, including both weekdays and weekends.

3.2 Trip Productions

The number of trips produced in any particular traffic analysis zone (TAZ) is determined using trip production rates based on that TAZ's socioeconomic or demographic information. Trip production rates can be developed from federal sources such as the Nationwide Personal Transportation Survey (NPTS), Census Transportation Planning Package (CTPP), and Journey To Work (JTW) data, and from local surveys. Different formulations may be required depending on the amount of data available for a particular state. One state, which had little NPTS coverage, made use of both NPTS and JTW trip production rates for their home-based work (HBW) rate (*2*):

HBW rate = (national NPTS rate) * (local JTW rate) / (national JTW rate)

This formulation was used to take advantage of both national-level NPTS data (viewed by modelers as more statistically reliable) and JTW data (which are more locally available). Traditional urban model production rates, such as those provided in National Cooperative Highway Research Program (NCHRP) Report 365, may also be used.

The choice of trip purpose included in the model has an important effect on the way trip productions are estimated. Although many trip purposes are represented in the available data, there are generally only three purposes modeled for intercity travel: business, non-business, and recreation. It is often necessary to condense the various trip purposes found in the available data into these three categories for use in a statewide model. There is a comparative wealth of information available regarding business trips. For example, the JTW was specially designed to provide information for home-based work trips. Some models have included a fourth trip purpose, for commute trips. To develop trip generation rates for other purposes, further assumptions are usually necessary, and both the quantity and quality of available data are more limited.

As cited in the *Guidebook on Statewide Travel Forecasting* (*2*), the Michigan passenger model trip production rates are developed through the following process. First, using NCHRP Report 365, generation rates are obtained for the various cross-classification groups. There are 60 different classification groups for the Michigan model, based on five household sizes (1, 2, 3, 4, and 5+ persons), three household income levels (low, medium, and high) and four geographical area sizes (small, medium, and large cities and rural areas). For example, in a large urban area, a low-income, single-occupant household will produce 3.7 trips per day. Second, using the proportion of total trips devoted for each purpose from the NPTS, the generated trips are divided among the purposes. For a large urban area, the following ratios are used for low-income, single-occupant households:

- 0.192 to home-based work
- 0.160 to home-based recreational
- 0.404 to home-based other
- 0.310 to non-home-based work
- 0.214 to non-home-based other

The resulting generation rates are obtained by taking the product of the two values. For instance,

0.192 * 3.7 = 0.71 trips per day for home-based work

0.160 * 3.7 = 0.59 trips per day for home-based recreational

The process is repeated for all 60 cross-classification groups.

3.3 Trip Attractions

Trip attraction rates (*2*) are more reliable than production rates. The same general methods used to develop production rates are also available to develop attraction rates. For instance, some statewide models have attraction rate equations that have been developed using federal data sources, including NPTS and JTW. Rates from NCHRP Report 365 may also be of value. As with urban models, production rates are usually considered more trustworthy than attraction rates, so attractions are adjusted to match productions by purpose at the end of the trip generation step. As with production rates, attraction rates are determined by trip purpose. A TAZ containing a national park would likely attract few business trips but would attract many recreational trips. Sites like national parks or military bases are sometimes represented in the network as special generators. Special generator sites are often modeled as trip attractions only, depending upon their characteristics. Site-specific information (from specialized surveys, e.g.) can be used to determine their attraction rates. If special surveys have not been undertaken, information from NCHRP Report 365 can be used to set the trip attraction rates. Michigan found that the weakest link in the whole model chain was trip attraction, so shortcuts at this stage of the modeling effort are inadvisable.

The effects of external travel in the model are estimated by using a national highway network. Use of a national network provides a method of modeling trips generated outside the local network. For a statewide model, the national network would likely consist of the interstate system and TAZs representing states or groups of states away from the area being modeled. With a national network it is easier to make use of national data (e.g., NPTS) to generate trips from distant states and later assign them into or through the local network. States that use national networks to help model external trips have found it beneficial to extend the local network into the surrounding states. In some cases this extended statewide network covers areas hundreds of miles into adjoining states. The extended network is used to provide both a more detailed accounting of trips generated in nearby states that may pass into or through the state being modeled, and to provide a way of buffering the distribution of trips generated outside the local network and being fed into it through external stations or national network links.

In general, the number of trips produced will not exactly match the number of trips attracted. This is to be expected, since entirely different submodels develop the numbers of trips produced or attracted. Since the production equations are generally considered to be more reliable than the attraction equations, it is common to adjust the attraction values of each TAZ such that the number of trips attracted for the whole model is equal to the number of trips produced. This process is carried out separately for each trip purpose.

Based on the above principles and methods, the model for trip generation is as follows:

E_{ip} = total trips generated from origin i for trip purpose p

$$= A_{ip} + \alpha_{ip} P_i + \beta_{ip} Y_i + \gamma_{ip} W_i + \delta \Sigma Z_i$$

where

A_{ip} = intrinsic qualitative factor of zone i (coefficient to be determined by the regression analysis)

P_i = population density for zone i for trip purpose p

Y_i = per capita personal income

W_i = percentage of workers

δ = number of persons above 18 / population

Z_i = dummy variable: Z_0 = 0 car, Z_1 = 1–2 cars, Z_2 = 2 + cars, or

\# of vehicles registered by county / # of households

A_{ip}, α_{ip}, β_{ip}, γ_{ip}, and δ are coefficients to be determined by regression analysis.

The model for trip attraction is expressed as

E_{jp} = total trips attracted to destination j for trip purpose p

$= A_{jp} + \varepsilon S_j + \zeta E_j$

where

A_{jp} = intrinsic qualitative factor of zone j (pull factor/special generator) for trip purpose p

εS_j = retail sales ($)

ζE_j = number of employees of zone j

Explanatory variables enter the model in a linear fashion at this time.

3.4 Trip Distribution

The trip distribution step determines the number of person trips that go between all pairs of zones. Usually, 24-hour person trips are distributed separately for each trip purpose. The results of the trip distribution step can be shown in the form of a matrix, with as many rows and columns as zones:

***A*'s**

	Zones	**1**	**2**	**3**
***P*'s**	**1**	180	780	939
	2	900	140	775
	3	950	750	200

Each row represents a production zone and each column represents an attraction zone. In the trip table shown, there are 775 trips between production zone 2 and attraction zone 3. Trip distribution is most often performed in urban area models using a gravity model. The number of trips between a zone pair is directly proportional to the magnitude of productions and attractions and inversely proportional to the square of the travel time.

This model uses the gravity model for travel forecasting but has added a variable for the friction factor. The *friction factor*, F_{ij}, is a function of zone separation based on time and cost. The separation by distance is represented by the *impedance*, or I_{ijp}. Total demand for mode m, for time period t, between zones i and j for trip purpose p, can be functionally represented as

$$X^t_{ijmp} = F(X^t_{ijp}, F_{ijmp})$$

where

X^t_{ijp} = total demand from origin i to destination j at time t, for trip purpose p

$= (E_{ip} E_{jp}) / I_{ijp}$

I_{ijp} = impedance or the distance decay factor (distance between i and j) for trip purpose p

F_{ijmp} = friction factor

The resulting equation for each mode m, time t, between zones i and j, for purpose p, becomes

$$X^t_{ijmp} = X^t_{ijp} F_{ijmp}$$

This equation will always yield a trip matrix that is consistent with the number of productions in each zone, as calculated in the trip generation step. But the trip matrix will not be consistent with the number of attractions; thus, this form of the gravity model is often referred to as being "singly constrained." The number of trips between any production zone i and any attraction zone j is proportional to the number of productions in i, proportional to the number of attractions in j, and inversely proportional to the impedance.

3.5 Mode Split

The mode-split step finds the number of trips using each available mode between a production and attraction pair. As with trip distribution, mode split is typically performed on 24-

hour person-trips. The mode-split step is most often found in forecasting models for large urban areas. Small cities tend to have low transit ridership, which is either ignored or treated as a fixed percentage of all trips. Mode-split models assume that travelers choose the best mode for themselves by weighing the characteristics of the trips for all available modes. The measure of trip goodness is called "utility." Since trips consume valuable resources, the value of utility is most often a negative number. The actual utility is unknown, as there are many personal factors and perceptions that influence each traveler's decision. However, major objective factors in the choice, such as travel time and cost, can be ascertained with some degree of accuracy. The mode-split model takes these objective factors as inputs but recognizes that the actual utility is known imprecisely when calculating mode shares. Some mode-split models include socioeconomic factors in their expression of utility. Still other mode-split models take into consideration factors related to access and the lack of one or more alternative modes for subgroups of travelers. Most urban models containing a mode-split step use a variation of the logit model, which organizes the modes into a hierarchy (see Figure 3.1).

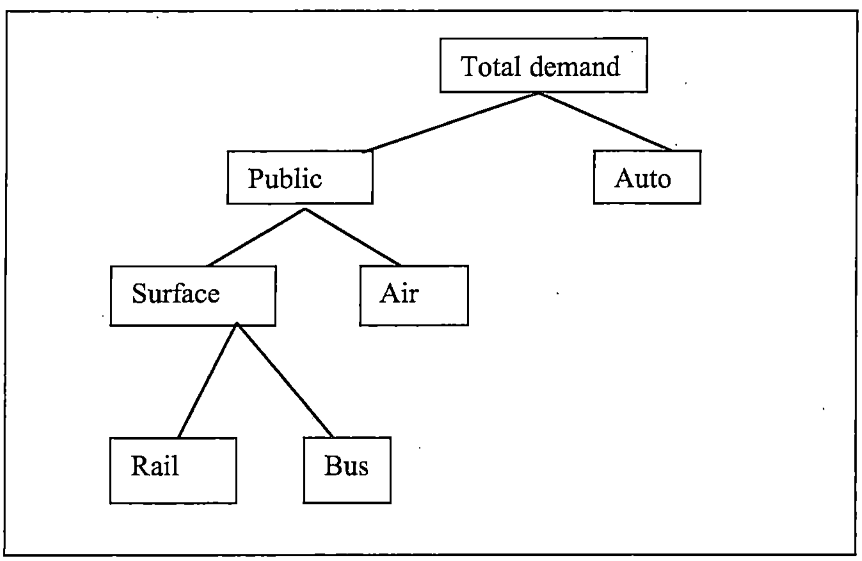


FIGURE 3.1 Logit Model Structure Hierarchy

The hierarchy implies that several decisions are made in the process of selecting a mode. For example, a decision is first made between public means of transport and automobile. Then, another decision is made regarding public, whether it is surface or air. Finally, another decision is made between rail and bus as means of public surface transport. Modes with similar characteristics are grouped together in a nest. The nested logit model (see Figure 3.2) has the ability to differentiate between pairs of modes that are complementary and pairs of modes that are competitive. Nested logit models are calibrated in much the same manner as regular logit models, using statistical estimation or adoption of default parameters. The statistical estimation process can also give a good indication of the best arrangements of modes and nests. However, professional judgment is required to assure that the model will give dependable results.

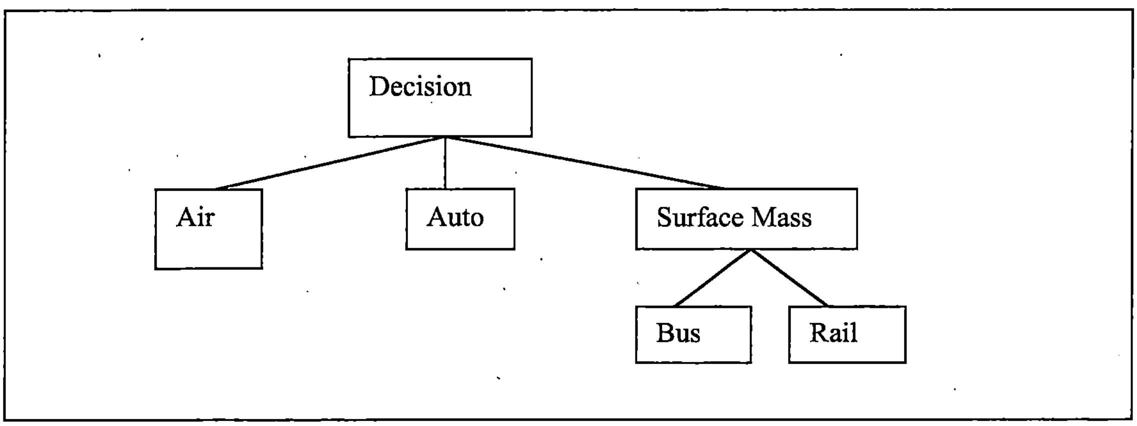


FIGURE 3.2 Example of Nested Logit Model

3.5.1 Co-Linearity

Many of the variables in the utility equation are roughly proportional to each other. For example, travel time is almost proportional to travel cost for most intercity modes. This proportionality is stronger for intercity trips than for urban trips. When two statistical variables are proportional in this manner, they are said to be co-linear. Co-linearity can result in strange values for estimated coefficients. If co-linearity is present in the data, it is important to apply the calibrated logit model to situations where the same type of proportionality holds.

3.5.2 Logical Nesting Structures

Quite different nesting structures can have almost the same statistical performance on data, but forecast very differently. Consequently, it is important to develop nesting structures that are logical, particularly by keeping like modes within the same nest. Professional judgment is necessary. Logit models require extensive data for calibration. Transferable parameters have not been developed for intercity mode-split models, and it is inappropriate to take coefficients from urban models.

3.5.3 Mode Choice

The factors influencing mode choice for this model are represented in a tabular form in Table 3.2 (and are discussed in detail in the Phase I report).

TABLE 3.2 Factors Influencing Mode Choice

Trip Purpose	Trip Characteristics	Service Characteristics	Traveler Characteristics
Work travel	Distance between origin and destination	Cost elastic Travel elastic Usually uniform annual pattern	Income
Business travel	Distance between origin and destination Length of stay Need for transport at destination	Cost inelastic Travel time elastic	Nature of employment
Recreation travel	Distance between origin and destination Length of stay Need for transport at destination	High cost elasticity Low time elasticity Low convenience elasticity Strong peaked temporal patterns	Income Group size
Personal travel	Distance between origin and destination Length of stay Need for transport at destination	Less flexibility Low time elasticity Low convenience elasticity	Income Group size

The modal choice model is functionally represented as

M_{ijmp} = percentage of trips by mode m, for travel from zone i to zone j, for trip purpose p

$= f(U_{ijmp})$

$f(U_{ijmp})$ = the total utility for mode m for travel from zone i to zone j, for trip purpose p

$= \lambda(M_{tmp}, M_{smp}, M_{trmp})$

where

M_{tmp} = vector of explanatory variables for trip characteristics for trip purpose p

M_{smp} = vector of explanatory variables for service characteristics for trip purpose p

M_{trmp} = vector of explanatory variables for socio-economic characteristics for trip purpose p

Estimates of travel utility for a transportation network can be generated as a function of generalized cost (GC), as shown below (this part of the model is based on the COMPASS Multimodal Demand Model) (*6*):

$U_{ijp} = f(GC_{ijp})$

where

GC_{ijp} = generalized cost of travel between zones i and j for trip purpose p

The generalized cost variable is used to estimate the impact of improvements in the transportation system on the overall level of trip-making, and so it needs to incorporate all the key modal attributes that affect an individual's decision to make trips. For the public modes (rail, bus, air), the generalized cost of travel includes all aspects of travel time (access, egress, in-vehicle times), travel cost (fares, tolls, parking charges), schedule convenience (frequency of service, convenience of arrival and departure times), and reliability. The generalized cost of travel between zones i and j for mode m and trip purpose p is calculated as

$$GC_{ijmp} = TT_{ijm} + TC_{ijmp}/VOT_{mp} + (VOF_{mp} * OH) / (VOT_{mp} * F_{ijm} * C_{ijm}) + VOR_{mp}\ \exp(-OTP_{ijm})/VOT_{mp}$$

where

TT_{ijm} = travel time between zones i and j for mode m (in-vehicle time + station wait time + connection wait time + access/egress time + interchange penalty), with waiting, connect and access/egress time multiplied by a factor (greater than 1) to account for the additional disutility felt by travelers for these activities

TC_{ijmp} = travel cost (fare + access/egress cost for public modes, operating costs for auto) between zones i and j for mode m and trip purpose p

VOT_{mp} = value of time for mode m and trip purpose p

VOF_{mp} = value of frequency for mode m and trip purpose p

OH = operating hours per week

F_{ijm} = frequency in departures per week between zones i and j for mode m

C_{ijm} = convenience factor of schedule times for travel between zones i and j for mode m

VOR_{mp} = value of reliability for mode m and trip purpose p

OTP_{ijm} = on-time performance for travel between zones i and j for mode m

As described in the Transportation Economics and Management Systems (TEMS), Inc., report, station wait time is the time spent at the station before departure and after arrival. Air travel generally has higher wait times because of security procedures at the airport, baggage checking and the difficulties of loading a plane. Air trips were assigned wait times of 45 minutes while rail and bus trips were assigned wait times of 30 minutes and 20 minutes, respectively. On trips with connections, there would be additional wait times incurred at the connecting station. Wait times are weighted higher than in-vehicle time in the generalized cost formula to reflect their higher disutility as found from previous studies. Wait times are weighted 70 percent higher than in-vehicle time for business trips and 90 percent higher for non-business trips. Similarly, access and egress time has a higher disutility than in-vehicle time. Access time tends to be more stressful for the traveler than in-vehicle time because of the uncertainty created by trying to catch the flight or train. Based on previous work, access time is weighted 30 percent higher than in-vehicle time for air travel and 80 percent higher for rail and bus travel.

TEMS found in previous studies that the physical act of transferring trains (or buses or planes) has a negative impact beyond the times involved. To account for this disutility, interchanges are penalized time equivalents. For both air and rail travel, each interchange for a trip results in 40 minutes being added to the business generalized cost and 30 minutes being added to the non-business generalized cost. For bus travel, the interchange penalties are 20 minutes and 15 minutes for business and non-business, respectively.

The third term in the generalized cost function converts the frequency attribute into time units. Operating hours divided by frequency is a measure of the headway or time between departures. In the stated preference surveys that produced the value of frequencies, tradeoffs were based on operating hours. Although there may appear to some double counting because the station wait time in the first term of the generalized cost function is included in this headway measure, it is not the headway time itself that is being added to the generalized cost. The third term represents the impact of perceived frequency valuations on generalized cost. TEMS has found it very convenient to measure this impact as a function of the headway. The convenience of the departure/arrival times was modeled only for the rail mode. It is incorporated in the generalized cost as a factor (C_{ijm}) multiplying the frequency. The factor is based on assigning each departure and arrival time in the timetable a desirability index derived from responses given by rail passengers about preferred arrival and departure times in the *1993 Illinois Rail Passenger Survey*. The product (F_{ijm} * C_{ijm}) was interpreted as a measure of the level of service.

3.6 Trip Assignment

For urban travel demand forecasting, trip assignment is the next logical step. But for multimodal travel demand forecasting, trip assignment should consider all travel demands, i.e., passenger and freight travel demand, simultaneously.

4 INTERCITY FREIGHT TRANSPORT COMPONENT

Recognizing the need to improve efficiency in the movement of commodities, ISTEA placed added emphasis on freight transportation. Freight transportation in Iowa has two primary components— agricultural products and manufactured products.

4.1 General Form

The quantitative variables that affect freight transportation demand include the value and weight of the freight, distance shipped, and transportation cost and speed. Ralston, Thakaran, and Liu, in their Bangladesh Transportation Modeling System, used time and cost equations to explain "logical links," which include loading or unloading and intermodal transfers (*7*). In this Ralston et al. model, any path between an origin and destination comprises a chain of logical and physical links. The sum of the costs and times over each link in a path determines the path cost and time. Logical links can be divided into two types, loading and unloading links and intermodal transfer links. Generalizing the Ralston et al. model as a guide, the functions and variables needed for each mode are

COST = (MFC + CFC) * NCM

where

MFC = fixed facilities cost ($ per ton)

CFC = fixed facilities cost due to commodity characteristics ($ per ton)

NCM = the node cost multiplier

and

TIME = (MFT + CFT) * NTM

where

MFT = loading or transfer time

CFT = time due to commodity characteristics

NTM = the node time multiplier

Other variables are VC = variable costs ($ per ton-mile) and S = speed.

The Ralston et al. model then computes a utility function, U_{ijkm}, for each shipment of commodity k, between origin and destination i and j, on mode m, which becomes the basis for the modal share (i.e., the probability of using mode m):

$P(m/ijk)$ = the probability of using mode m given that there is to be a shipment of commodity k from i to j

$$= \exp(U_{ijkm}) / \sum \exp(U_{ijkm})$$

where

U_{ijkm} = the utility associated with shipping commodity k from the origin i to destination j via mode m

Thus, based on the modal share and the amount (tons) of commodity k that needs to be shipped from one region to another, the total demand for a particular mode can be determined.

4.2 Agricultural Products

4.2.1 Example of Corn and Soybeans

The particular transportation demands for corn and soybeans have been modeled by Gervais, McVey, and Baumel (*8*). Their linear programming model simulates the decision-making process for farms and grain elevators, by determining the amounts of corn and soybeans to be shipped, based on estimated production and estimated farm usage (for feeding of livestock and for seed). Gervais et al. include the effects of elevator and market bid prices and transportation costs per bushel.

4.2.2 Grain Volumes

Grain volumes are converted to weight by multiplying bushels times a constant. An average bushel of corn weights 56 pounds (or 0.028 tons). One metric ton (2204.6 pounds) of soybeans is 36.74 bushels (*9*), so one bushel of soybeans weighs an average of 60 pounds (or 0.030 tons) per bushel. Rounding both to two decimal places gives a bushel weight of corn or beans as 0.03 tons.

4.2.3 Farm-to-Elevator Transportation Costs

When grain is shipped from a farm to an elevator, several kinds of vehicles can be used, such as tractor-wagons, trucks, and semis. Hanson et al. divided transportation cost into fuel cost, oil cost, tire cost, maintenance cost, travel time cost, and variable cost by surface type to estimate each cost component for various kinds of vehicles (*10*). (The details of this estimation method are explained in Appendix A.)

Using this method, Gervais et al. presented farm-to-elevator grain transportation costs. Total variable costs per mile for each vehicle were estimated by summing fuel cost, oil cost, tire cost, maintenance cost, and travel time cost. To obtain the estimated variable cost per bushel-mile, the total variable cost was divided by the capacity (in bushels) for each type of vehicle. Transportation cost for commercial semis were obtained from industry executives. Table 4.1 shows the estimated costs thus obtained.

TABLE 4.1 Estimated Transportation Costs

Vehicle Type	Variable Cost (Cents per Bushel-Mile)
Tractor-wagon:	
One-wagon	0.38
Two-wagon	0.22
Farmer-owned truck:	
Single-axle	0.143
Tandem-axle	0.107
Semi	0.074
Commercial semi	0.111

Source: J.-P. Gervais and C. P. Baumel. The Iowa Grain Flow Survey: Where and How Iowa Grain Producers Ship Corn and Soybeans. *Journal of the Transportation Research Forum*, Vol. 37, No. 1, 1998 (*1*).

4.2.4 Elevator-to-Market Transportation Costs

From elevators to markets, possible transportation modes are semi-trailers, railcars, and barges. Barge transportation was not considered in the Gervais et al. model. The generalized freight transportation model includes variable m (for "mode"), which will permit this alternative, as much Iowa grain is shipped on the Mississippi River (and, to a lesser extent, on the Missouri River). To estimate the transportation cost per bushel-mile for semis, the same cost estimates used for farms can be applied. The distance between elevators and possible markets is measured using the computer software TransCAD. The transportation cost from elevators to markets for each grain, per bushel-mile (using semis), is obtained by multiplying the distance and the estimated cost per bushel-mile.

Rail transportation costs are estimated from the commercial rates that each rail company charges for grain transportation. Nineteen railroad companies operate in Iowa, and they have their own freight transportation rates for corn and soybeans.

4.3 Manufactured Products

4.3.1 Trip Generation

The aggregated origin-destination data from the Commodity Flow Survey (CFS) for each commodity in every zone (county) provides estimates of productions and attractions. The CFS data are for Bureau of Economic Analysis economic areas. To translate the Iowa commodity data to the county level, the tons and value of commodity shipped may be related to the population, employment, and farm acreage of the corresponding BEA area. A conversion method is

county origin tons = BEA origin tons * (county employment/BEA employment)

county destination tons = BEA destination tons * (county consumption/BEA consumption)

4.3.2 Trip Distribution

The gravity model used for trip distribution is (*12*):

$$V_{ij} = (P_i \, A_j \, F_{ij} \, K_{ij}) \, / \, \Sigma \, A_x \, F_{ix} \, K_{ix}$$

where

V_{ij} = volume of freight from zone i to zone j

P_i = freight volume produced at zone i

A_j = freight volume attracted to zone j

F_{ij} = trip impedance factor from zone i to zone j, using travel time

K_{ij} = interzonal adjustment factor from zone i to zone j

4.3.3 Mode Choice

The amounts shipped, U_{ijkm}, by mode m is a function of cost from i to j for commodity k for mode m, and time t to go from i to j for commodity k by mode m:

$$U_{ijkm} = F(C_{ijkm}, T_{ijkm})$$

where

$C_{ijkm} = L * VC * CFC * MFC * LCM * SCM + I_i (CFC * MFC * LCM * SCM)$

L = length of link (data from network)

VC = variable cost ($ per ton-km)

CFC = fixed facilities cost ($ per ton), due to commodity characteristics

MFC = fixed facilities cost ($ per ton)

LCM = link's unique cost (multiplier nominally 1), reflecting the link's state of repair

SCM = mode's seasonality cost (multiplier nominally 1)

I_i = dummy variable: $I = 0$, no intermodal transfer; $I = 1$, intermodal transfer

and

$T_{ijkm} = (L/S) * MFT * CFT * LTM * STM + I_i (MFT * CFT * LCM * STM)$

L = length of link

S = speed (mph)

MFT = loading or transfer time

CFT = time due to the commodity characteristics

LTM = link's unique time (multiplier nominally 1), reflecting link's state of repair

STM = mode's seasonality time (multiplier nominally 1)

The format of the modal amount equation for product U becomes

$$U_{ijkm} = B_{1k} C_{ijkm} + B_{2k} T_{ijkm} V_k + B_{3k} d_1 + B_{4k} d_2$$

where

B_{1k} = weight (to be determined, expected negative)

B_{2k} = weight (to be determined, expected negative)

V_k = value of commodity k

B_{3k} = weight (to be determined, either sign)

d_1 = dummy variable (1, if road; 0 otherwise)

B_{4k} = weight (to be determined, either sign)

d_2 = dummy variable (1 if rail; 0 otherwise)

The modal share (the probability of using mode *m* from zone *i* to zone *j* by commodity *k*) is based on the amounts calculated above:

$$P_{ijkm} = \exp(U_{ijkm}) / \Sigma \exp(U_{ijkm})$$

4.4 Total Transportation Demand (Passenger and Freight)

Eventually, the three different categories of traffic modeled above (passengers, grain, and other freight) will share the same roadways, railways, airways, and waterways, and travel models will need to indicate the total through some universal measurement. While the outputs of the cost equations are expressed in dollars, the volumes transported are passengers, bushels, and tons. Most freight data are expressed in tons and ton-miles, just as passenger data appear as passengers and passenger-miles. Consistency would suggest that passenger counts could be converted to average weights, and all vehicles could be listed by weights as well. Alternative measures could include cubic volumes (e.g., cubic feet, cubic meters), vehicles, vehicle axles, wheels, and containers (e.g., twenty-foot equivalent unit [TEU]). Weight and distance were selected here as the more universal and familiar measures.

Two modes dominate passenger transportation: automobile and commercial airlines. For load planning purposes, airline estimates vary between 170 pounds (*13*) and 200 pounds for adults and 80 pounds for children under 12 years old (*14*). Both are well above the average human weight of 70 kg (i.e., 154.3 pounds) (*15*). Estimating a passenger weight of 0.1 ton gives a reasonable allowance for luggage and personal effects.

Thus total transportation demand, including freight, from origin i to destination j, on mode m, will be

$$U_{\text{ijm}} = U_{\text{ijmPassenger}} + U_{\text{ijmGrain}} + U_{\text{ijmFreight}}$$

Constraints of individual modes will be applied to this overall volume figure rather than on the individual components.

5 DATA SOURCE IDENTIFICATION

This section gives an overview of the needed and available data sources for the model. (In Appendix B, the data requirements of the model are illustrated sequentially.) The most important data sources that might be used for the model are the Census data, National Personal Transportation Survey (NPTS), Commodity Flow Survey (CFS) data for freight, and National Transportation Atlas Database (NTAD) for highway, rail, water, and airway networks.

5.1 Census Data

CensusCD+Maps by GeoLytics is a software package that combines demographic statistics with the ability to easily select, map, and export data. Data reports and thematically shaded color maps are created from the one CD-ROM. CensusCD+Maps includes all of the data, map boundaries, and software in one package. The data on CensusCD+Maps provide details about the population and housing of the United States. It has demographic information down to the neighborhood level (block groups) from the most recent U.S. Census available at the time (1990 STF3 A, B, C, and D), along with more current estimates for 1997 and projections for 2002. It also has estimates and projections of consumer spending at the neighborhood level. CensusCD+Maps combines this set of demographic data with statistics, going back to 1969, for every county in the United States (*16*).

5.2 Nationwide Personal Transportation Survey

In conjunction with the American Travel Survey (ATS), NPTS provides a total picture of passenger travel in the United States. The NPTS is particularly well suited for measuring repetitive, local travel. The ATS and NPTS specify where Americans travel, how they get there, and why they go there. NPTS data are intended to provide a record of travel by trip purpose and mode, social and economic characteristics of the trip makers, changes in vehicle ownership, vehicle and fuel usage, and the changing travel patterns of women.

The NPTS is a household travel survey that provides data on the amount and nature of personal travel in the United States. Data were collected from a sample of households, on all personal trips, by all modes, for all purposes. Interviews were conducted for all persons age 5 and older in the sampled households. Persons 14 and older were interviewed directly and a household adult was asked to report for children of ages 5 to 13. The sample was stratified by region of the country, size of the metropolitan area, and presence or absence of a subway system. Expansion factors were applied to obtain annual, national estimates of trips, miles of travel, household vehicles, etc. The NPTS data provide an authoritative source for the characteristics of personal travel, particularly as linked to the demographics of the traveler, for the nation. These data allow analysis of trends in travel and the relative use of different modes of transportation.

The 1995 NPTS was conducted by Research Triangle Institute and was sponsored by the following U.S. Department of Transportation agencies: Bureau of Transportation Statistics (BTS), Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and National Highway Traffic Safety Administration (NHTSA) (*17*).

5.3 Commodity Flow Data

5.3.1 Transearch

Commodity flow movements are available in the Transearch database from Reebie Associates. Information in the Transearch data includes origin state, Bureau of Economic Analysis origin region, destination state, and BEA destination region for each origin-destination pairing. The data are further classified by Standard Industrial Commodity (SIC) code and volume of freight by shipping mode in short tons (2,000 lbs.). Transearch data as purchased by the Iowa

Department of Transportation (Iowa DOT) show only those movements with origins and/or destinations within Iowa and do not include bridge traffic through the state.

The Transearch database uses several primary sources of data, as outlined in the *Transearch Reference Manual* A partial list includes Railroad Waybill Sample, Commodity Flow Survey, U.S. Census Survey of Manufacturers, annual motor carrier industry financial and operating statistics, annual county employment and population data, and actual truckload traffic flow data as reported by major truckload motor carriers. The data were then converted into the common Transearch framework, while ensuring the elimination of any potential double counting from partially overlapping data sources. These data were logged in 1992, establishing a date for all other model assumptions and data sources (*12*).

5.3.2 Commodity Flow Survey

The Commodity Flow Survey contains data on shipments including exports, by domestic establishments in manufacturing, wholesaling, mining, and selected other industries. The CFS is designed to produce measures of the movement of goods by major type of commodity shipped and modes of transportation used. The Bureau of the Census conducted the CFS with support from the U.S. Department of Transportation (*18*, *19*).

The source of the frame used for sampling in 1992 was the Standard Statistical Establishment List (SSEL) of separate business locations with paid employees, maintained by the Census Bureau. Establishments in these trade areas that had non-zero payroll in at least one quarter of 1991 were included in the sampling frame of approximately 800,000 establishments.

5.3.3 1993 CFS Example

The 1993 CFS covered firms in mining, manufacturing and wholesale trade, and selected retail and service industries. The survey also covered selected auxiliary establishments (e.g., warehouses) of in-scope multi-unit and retail companies. The survey coverage excluded establishments classified as farms, forestry, fisheries, oil and gas extraction, governments, construction, transportation, households, foreign establishments, and most establishments in retail and services.

The 1993 Commodity Flow Survey is an establishment-based shipper survey that used mailout and mailback data collection. Respondents were asked to select a sample of their outbound shipments and to report, for each sampled shipment, the major commodity, weight, value, transportation mode(s), origin, destination, and indicators of whether the shipment was an export, hazardous material, or container..For multi-commodity shipments, the respondents were instructed to report the commodity that made up the greatest percentage of the shipment's weight.

The 1993 survey used two report forms: the CFS1000 (the primary questionnaire) and the CFS2000 (which was sent in the fourth quarter to a subsample of establishments). The CFS2000 contained additional questions about the establishment's transportation equipment and access to shipping facilities. A sample of 200,000 domestic establishments was randomly selected from a universe of about 900,000 establishments. Each selected establishment reported a sample of approximately 30 outbound shipments for a two-week period in each of the four calendar quarters of 1993, producing a total sample of about 13 million shipments. For each sampled shipment, zip code of origin and destination, five-digit Standard Transportation Commodity Classification (STCC) code, weight, value, and modes of transport have been provided. Information was also obtained on whether the shipment was containerized, a hazardous material, or an export (*20*). Route distance for each mode for each shipment was imputed from a mode-distance table developed by Oak Ridge National Laboratory. Distance, in turn, was used to compute ton-mileage by mode of transport.

Based on experience with the 1993 survey, additional measures to reduce respondent burden have been implemented for 1997: the sample size was cut in half, a reduced shipping period was covered, the number of shipments covered was reduced, improvements were made to the questionnaire and instructions, and special reporting arrangements were made.

The 1993 CFS is available in printed or electronic form from the Bureau of Transportation Statistics (maps are available in a user query option at http://www.bts.gov/programs/gis/maps/ in the "Interstate Commodity Wing.") Also available are a national summary (selected highlights by the BTS), detailed national tabulations by the Bureau of the Census, state summaries by the BTS, individual state reports by the Bureau of the Census and the BTS, national transportation analysis region (NTAR)–to–NTAR flows on CD-ROM, and maps of commodity flows and NTARs.

5.4 National Transportation Atlas Database

NTAD (*21*) is a collection of geo-spatial databases developed by the U.S. Department of Transportation and other federal agencies depicting transportation facilities, networks, and services of national significance. It contains a compilation of geographic databases that provide the infrastructure for national planning and policy initiatives for the U.S. Department of Transportation. These data sets include geo-spatial information for transportation modal networks and intermodal terminals, and related attribute information.

The NTAD databases are designed to be used with Geographic Information System (GIS; see Chapter 7) software packages to locate transportation features and provide a framework for transportation network analysis. The databases are most useful at the national level but have major applications on regional, state, and local scales throughout the transportation community.

NTAD is a cooperative effort of the U.S. Department of Transportation and many other federal agencies. The NTAD database is updated annually, incorporating updates of attribute fields as well as all corrections and enhancements made to the geography and/or topology since the previous release. Between each version release, the Bureau of Transportation Statistics BTS posts interim updates on its Internet site, incorporating corrections identified by users and enhancement work in progress. Interim updates include both a transaction database, containing only those records which have been updated since the last major release, and a transaction log file, identifying what specific changes were made to each updated record.

The first "usable" NTAD was in 1996. NTAD 1997 includes geo-spatial information for national transportation modal networks and intermodal terminals, and related attributes developed by U.S. Department of Transportation and other federal agencies. NORTAD is a special release of NTAD for 1998 that includes border crossings between Canada, Mexico, and the United States. NTAD can be obtained for no charge by downloading from the BTS web site or by requesting CD-ROMs from BTS.

6 TRANSPORT NETWORK DEVELOPMENT

6.1 Delineation of Traffic Analysis Zones

The first step to model development is to define regions representing traffic analysis zones (*12*). As discussed in Chapter 1, the proposed unit of aggregation for state transportation data is the county level, as it is the accepted level of geographical detail in the sources cited.

Outside the state, the zonal structure of the provided Reebie Transearch database (for the freight model) defines the geographic level of aggregation. The zonal structure of the Reebie data was based on Bureau of Economic Analysis region (within and near Iowa) and aggregated BEA regions (which are proportionally larger with increased distance from Iowa). Only six BEA regions lie within Iowa, which would provide too coarse a basis for freight flows on the state's transportation network. Therefore, counties were used as TAZs within the state (99 counties). Some BEA regions cross Iowa's borders; in such a case, Iowa counties are removed from the BEA region and the remainder comprise one TAZ outside the state. This procedure provides for a national total of 145 TAZs in the model. The TAZ definition was then used to create coverage in the GIS environment represented in Figure 6.1.

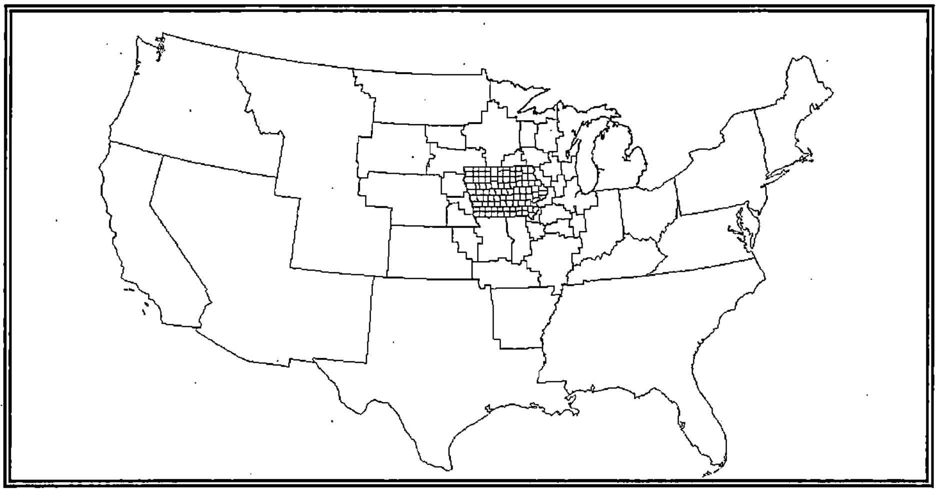


FIGURE 6.1 Delineation of Traffic Zones

6.2 HighwayNetwork

The network of the U.S. Interstate highway system and Iowa primary (state-owned) roads represents about 40,000 miles of roads outside Iowa and some 10,000 miles of road inside the state (see Figure 6.2). The two network components were combined and attributed with free-flow speed.

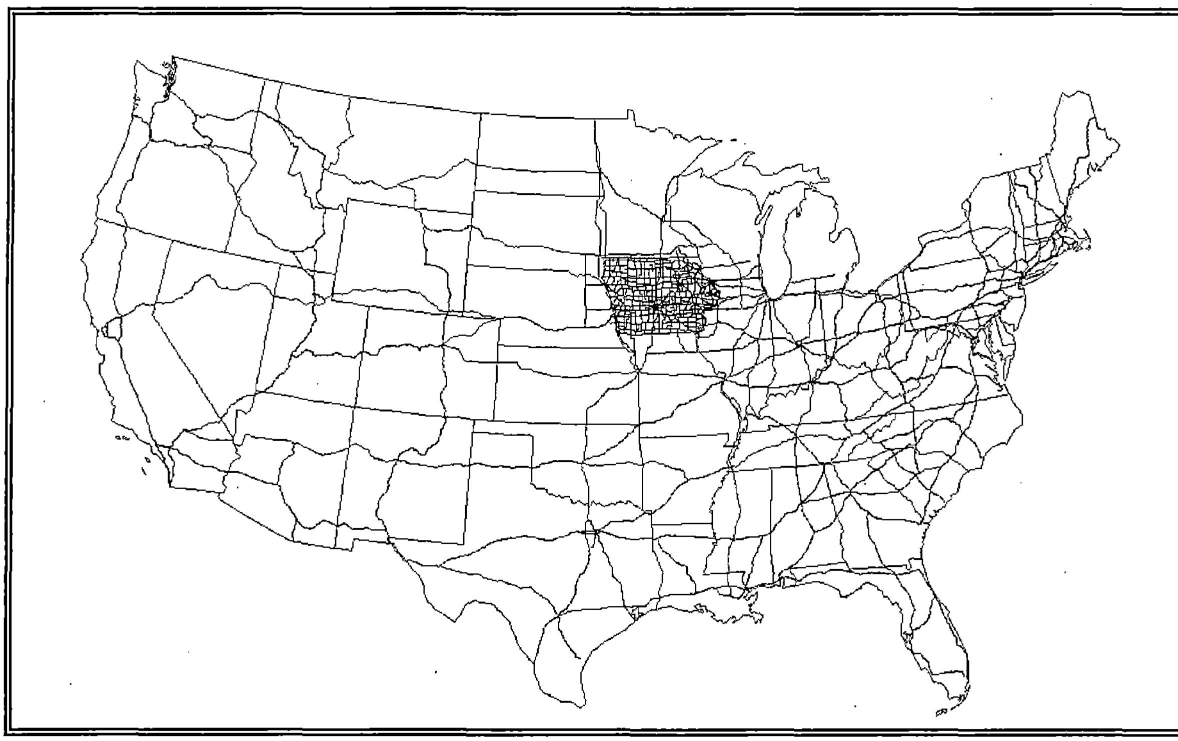


FIGURE 6.2 Delineation of Highway and Road Network

In the combined network, many Iowa primary highways appear to terminate at the state border. In reality, these roads continue on as other states' highways. However, inclusion of other states' highways would lead to the development of a large, unwieldy network. Further, as proximity decreased, this level of detail was not considered important to represent accurate network flows inside Iowa. An assumption was made that, once outside Iowa, trucks would choose to travel the Interstate highways by taking the shortest path to this system. To represent this assumption, artificial connectors were added outside the Iowa border, which represented reasonable paths to the nearest Interstate highway. The connectors were placed such that they may follow actual state highway routes but do not reflect all such possible routes. Finally, centroid connectors were added to tie TAZs to the network.

This "link only" GIS network was then converted to a link-node network for the travel demand-modeling package (TRANPLAN). The programs for this conversion process prepare a new GIS database and automatically populate its link field with beginning and ending node numbers, Cartesian coordinates, length, speed, link ID, and highway name (all required by the modeling package). The node table is also automatically attributed with node numbers and coordinates by the same process.

6.3 RailroadNetwork

The railroad network for the entire nation is available in GIS format in the BTS National Transportation Atlas Database, at scales of 1:100,000, or 1:2,000,000. This model utilizes the 1:2 million scale, with reported traffic levels classifying these rail lines as mainline and branch line. The network of railroads within Iowa consists of all currently active rail facilities. Beyond Iowa boundaries, this network can by thinned to mainline routes of major railroad operators, as smaller operators will not usually intercept movements of long-distance rail hauls. See Figure 6.3.

Within Iowa, the railroad network consists of all rail lines in the BTS data set that correspond to those lines present in the 1992 Iowa Railroad Service Map from the Iowa DOT. From these maps and discussions with Iowa DOT planners, it was evident that many Iowa rail facilities in the BTS map had long ago been removed from service (abandoned or rail banked). Thus, the BTS data could not be used directly in Iowa without modification.

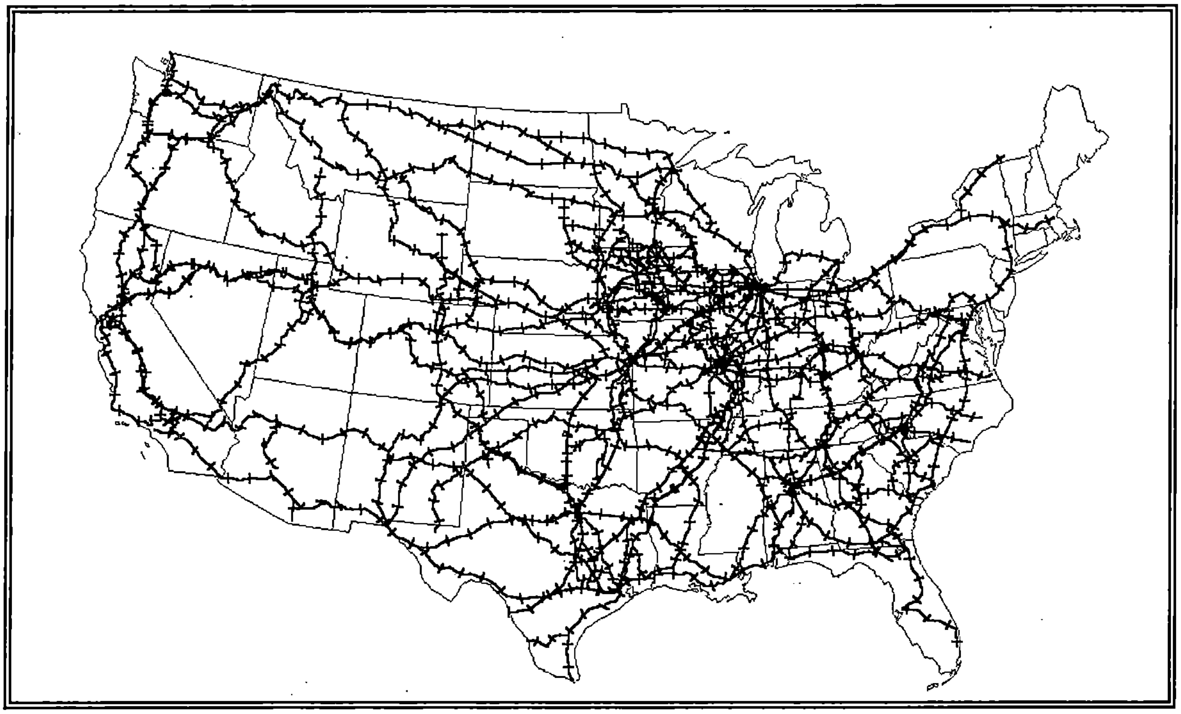


FIGURE 6.3 Delineation of Rail Network

Maps from the Class I railroads operating in Iowa (Burlington Northern–Santa Fe, Union Pacific, CSX Transportation, and Norfolk Southern Railway) were imported into GIS as raster images, which gives them an accurate geographic position. Using this number of railroad operators provided a geographically dense coverage for a railroad network reaching all TAZs.

Not every centroid for each TAZ is connected to the rail network. This is observed only in Iowa, where rail availability in each county is determined by the existence of a rail line within that region. In addition, each industry group within that TAZ may not have access to that rail link. This latter point is ignored in this study, as it is assumed that where a rail line exists in that zone, it is also accessible to each industry in that zone.

7 GEOGRAPHIC INFORMATION SYSTEM DATABASE

This chapter involves the design and development of the GIS database for geographic feature and attribute data. As explained previously, TAZs in this model are counties for Iowa and BEA regions for areas external to Iowa. With county-level modeling, there is less temptation to match flows at a small (census tract) level, when the model is really based on information from a much larger (county-level) scale. At the county level of aggregation, it is also more likely that a sufficient number of data samples can be found to calibrate logit-style models and other more "advanced" modeling structures (*2*).

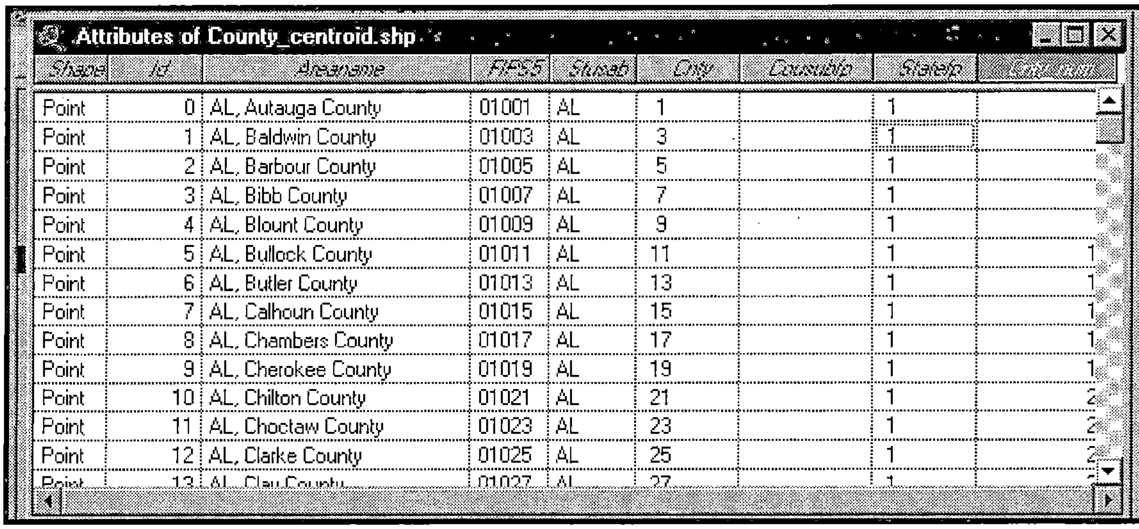
This chapter includes the delineation of transportation networks, traffic zones, and network element characteristics for all transportation modes. Types of network characteristic data that will be developed are link travel times, link travel costs, link capacities, nodal loading and transfer times, nodal loading and transfer costs, and nodal impedances and restrictions. Summaries of cost and modal choice equations are compiled in Appendices A and B. Structures of the TAZs and the data table structures are in Appendices C and D, respectively. The data are available in MapInfo format (consistent with the TAZ structure developed by Souleyrette and Pressig) but will need to be converted into TransCAD acceptable format (*12*).

7.1 Aggregation and Disaggregation of Attribute Data into Existing TAZ Structure

7.1.1 Creation of County-to-TAZ Conversion Table

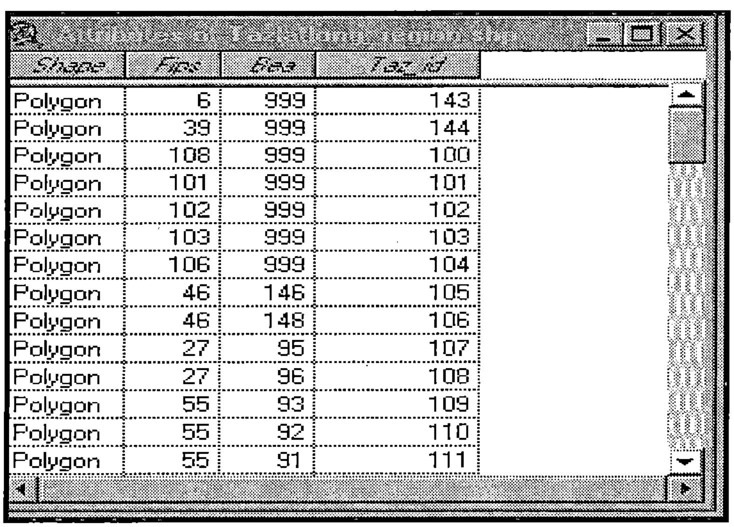
1. In ArcView, tables representing TAZ regions (Tazlatlong_region.shp) and county centroids (County_centroid.shp) are opened.

2. A spatial join is made between the two tables. This links the TAZ_ID with the AreaKey for all counties in the United States. Counties that do not have TAZ_IDs are deleted.



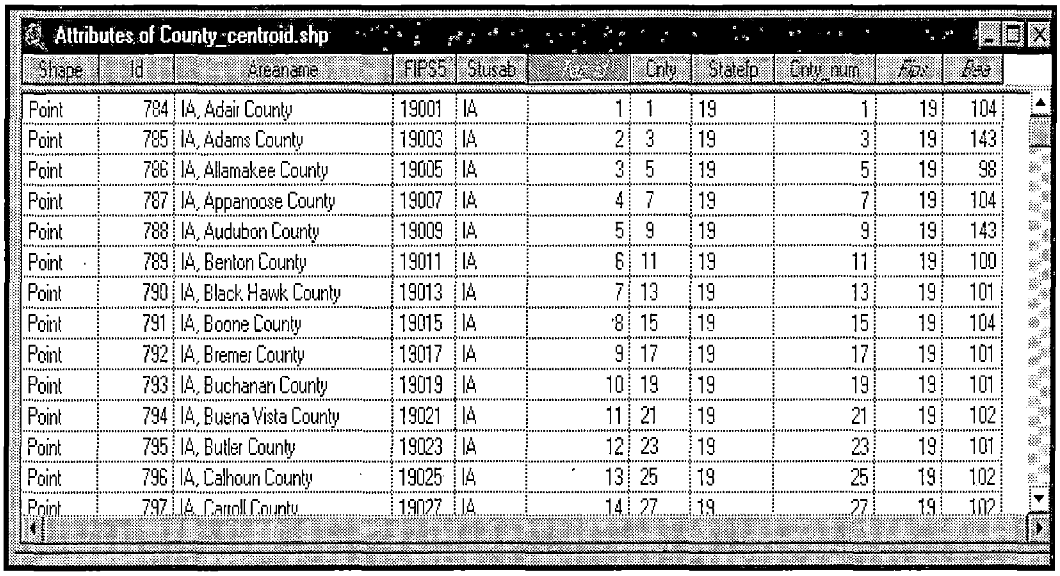
Attributes of County_centroid.shp

Shape	Id	Areaname	FIPS5	Stmab	Cnty	Cousubfp	Statefp	
Point	0	AL, Autauga County	01001	AL	1		1	
Point	1	AL, Baldwin County	01003	AL	3		1	
Point	2	AL, Barbour County	01005	AL	5		1	
Point	3	AL, Bibb County	01007	AL	7		1	
Point	4	AL, Blount County	01009	AL	9		1	
Point	5	AL, Bullock County	01011	AL	11		1	1
Point	6	AL, Butler County	01013	AL	13		1	1
Point	7	AL, Calhoun County	01015	AL	15		1	1
Point	8	AL, Chambers County	01017	AL	17		1	1
Point	9	AL, Cherokee County	01019	AL	19		1	1
Point	10	AL, Chilton County	01021	AL	21		1	2
Point	11	AL, Choctaw County	01023	AL	23		1	2
Point	12	AL, Clarke County	01025	AL	25		1	2
Point	13	AL, Clay County	01027	AL	27		1	



Shape	Fips	Bea	Taz_id
Polygon	6	999	143
Polygon	39	999	144
Polygon	108	999	100
Polygon	101	999	101
Polygon	102	999	102
Polygon	103	999	103
Polygon	106	999	104
Polygon	46	146	105
Polygon	46	148	106
Polygon	27	95	107
Polygon	27	96	108
Polygon	55	93	109
Polygon	55	92	110
Polygon	55	91	111

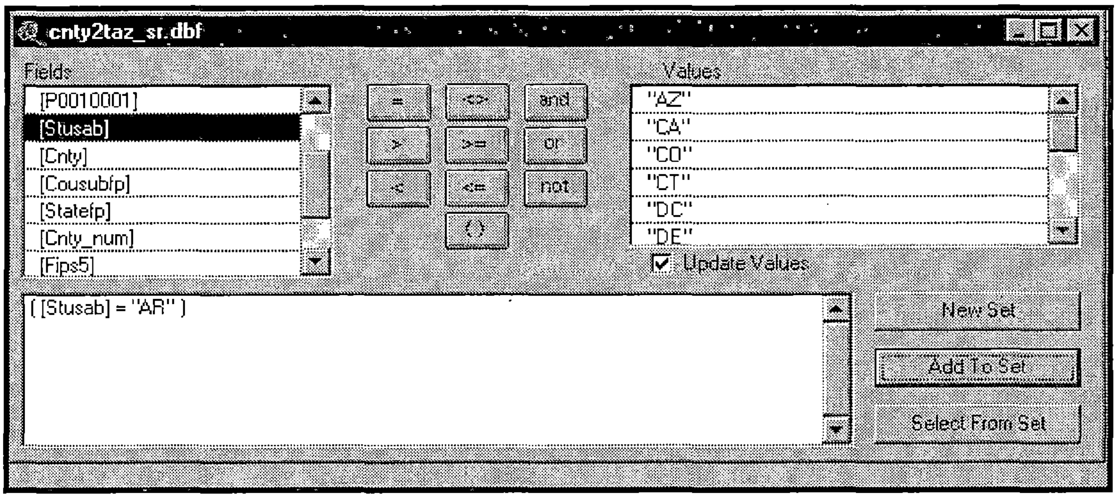
3. The new table formed after the spatial join links the AreaKey (FIPS5) with the TAZ_ID. The new table (cnty2taz.shp) formed is as follows:



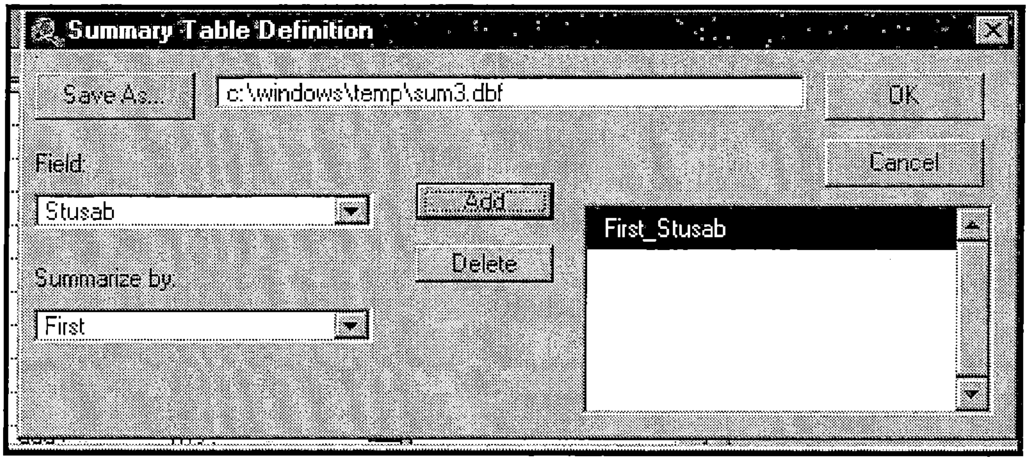
Attributes of County_centroid.shp

Shape	Id	Areaname	FIPS5	Stusab	[illegible]	Cnty	Statefp	Cnty_num	Fips	Reg
Point	784	IA, Adair County	19001	IA	1	1	19	1	19	104
Point	785	IA, Adams County	19003	IA	2	3	19	3	19	143
Point	786	IA, Allamakee County	19005	IA	3	5	19	5	19	98
Point	787	IA, Appanoose County	19007	IA	4	7	19	7	19	104
Point	788	IA, Audubon County	19009	IA	5	9	19	9	19	143
Point	789	IA, Benton County	19011	IA	6	11	19	11	19	100
Point	790	IA, Black Hawk County	19013	IA	7	13	19	13	19	101
Point	791	IA, Boone County	19015	IA	8	15	19	15	19	104
Point	792	IA, Bremer County	19017	IA	9	17	19	17	19	101
Point	793	IA, Buchanan County	19019	IA	10	19	19	19	19	101
Point	794	IA, Buena Vista County	19021	IA	11	21	19	21	19	102
Point	795	IA, Butler County	19023	IA	12	23	19	23	19	101
Point	796	IA, Calhoun County	19025	IA	13	25	19	25	19	102
Point	797	IA, Carroll County	19027	IA	14	27	19	27	19	102

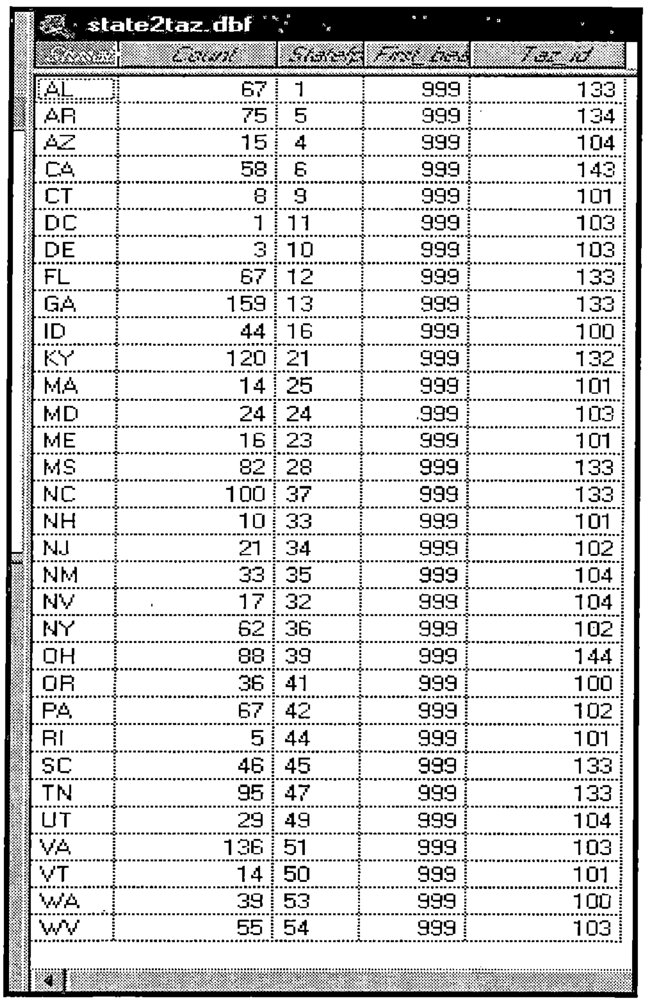
4. The TAZs are the 99 Iowa counties, collections of counties from nearby states, states, and aggregations of distant states. The selection for states is done using the query tool as follows:



5. These selections are exported in *.dbf format. The selected states and aggregation of states as TAZs are summarized:



6. The output after that summarization is as follows:

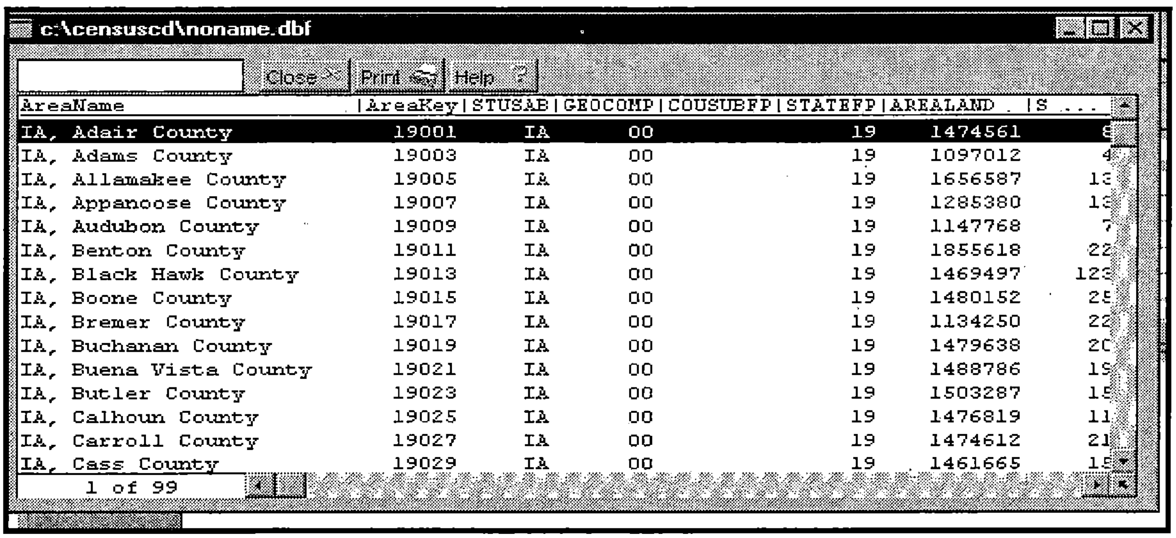


[illegible]	Count	Statef	First_bea	Taz_id
AL	67	1	999	133
AR	75	5	999	134
AZ	15	4	999	104
CA	58	6	999	143
CT	8	9	999	101
DC	1	11	999	103
DE	3	10	999	103
FL	67	12	999	133
GA	159	13	999	133
ID	44	16	999	100
KY	120	21	999	132
MA	14	25	999	101
MD	24	24	999	103
ME	16	23	999	101
MS	82	28	999	133
NC	100	37	999	133
NH	10	33	999	101
NJ	21	34	999	102
NM	33	35	999	104
NV	17	32	999	104
NY	62	36	999	102
OH	88	39	999	144
OR	36	41	999	100
PA	67	42	999	102
RI	5	44	999	101
SC	46	45	999	133
TN	95	47	999	133
UT	29	49	999	104
VA	136	51	999	103
VT	14	50	999	101
WA	39	53	999	100
WV	55	54	999	103

7. Then a reverse selection is made, and Iowa counties are unselected from this new set. This set is also exported in *.dbf format. Similarly, Iowa counties are also selected and exported in *.dbf format. Now three tables in *.dbf format having TAZ_ID linked to AreaKey are formed. These need to be linked to the data from CensusCD. The joining variable is the AreaKey.

7.1.2 Creation of Socio-Economic Database

1. From CensusCD, a database is formed (Appendix B) for 99 Iowa counties, which are TAZs 1–99. The format is partially represented below:



c:\censuscd\noname.dbf

Close Print Help

AreaName	AreaKey	STUSAB	GEOCOMP	COUSUBFP	STATEFP	AREALAND	S ...
IA, Adair County	19001	IA	00		19	1474561	8
IA, Adams County	19003	IA	00		19	1097012	4
IA, Allamakee County	19005	IA	00		19	1656587	13
IA, Appanoose County	19007	IA	00		19	1285380	13
IA, Audubon County	19009	IA	00		19	1147768	7
IA, Benton County	19011	IA	00		19	1855618	22
IA, Black Hawk County	19013	IA	00		19	1469497	123
IA, Boone County	19015	IA	00		19	1480152	25
IA, Bremer County	19017	IA	00		19	1134250	22
IA, Buchanan County	19019	IA	00		19	1479638	20
IA, Buena Vista County	19021	IA	00		19	1488786	19
IA, Butler County	19023	IA	00		19	1503287	15
IA, Calhoun County	19025	IA	00		19	1476819	11
IA, Carroll County	19027	IA	00		19	1474612	21
IA, Cass County	19029	IA	00		19	1461665	15

1 of 99

2. Similarly, a database is created from CensusCD for the following.

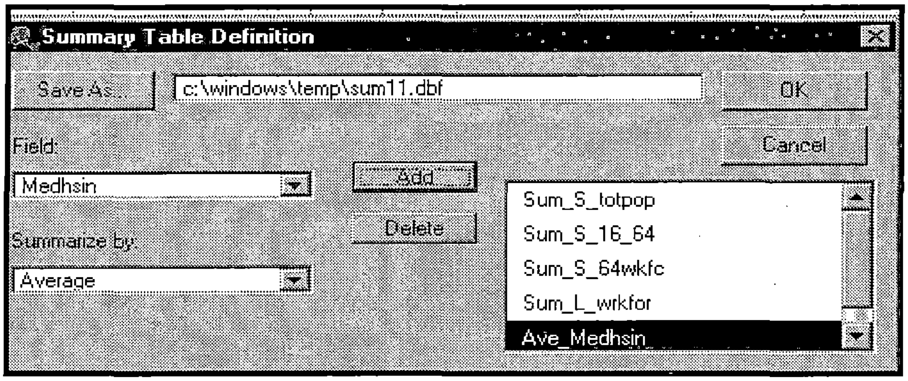
Alabama	Maine	Oregon
Arizona	Maryland	Pennsylvania
Arkansas	Massachusetts	Rhode Island
California	Mississippi	South Carolina
Connecticut	Nevada	Tennessee
Delaware	New Hampshire	Utah
District of Columbia	New Jersey	Vermont
Florida	New Mexico	Virginia
Georgia	New York	Washington
Idaho	North Carolina	West Virginia
Kentucky	Ohio	

3. Similarly, databases are formed for the remaining states with county-level data.

4. The databases formed from CensusCD are opened in ArcView. These need to be linked to the files containing the TAZ_ID. They are joined with these files and the new structure for the three files is as follows:

TAZ_ID	AREAKEY	DATA

5. The state data and other county data need to be summarized by TAZ_ID. This is done by summarizing by TAZ_ID and by other variables in the following manner:



6. The output of this process is the following spreadsheet, which presents data by TAZ_ID:

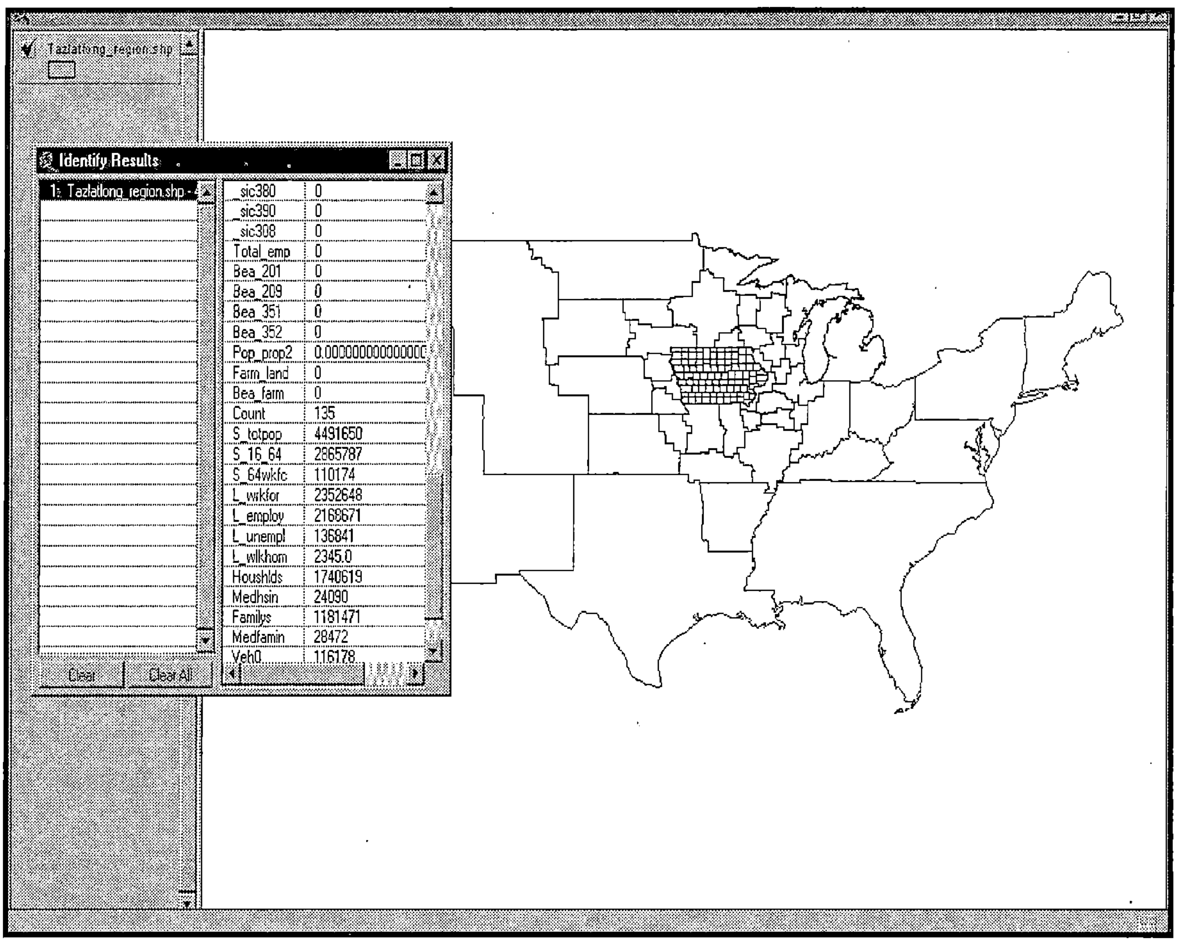
sum8.dbf

Taz_id	Count	Sum_S_totpop	Sum_S_16_64	Sum_S_64wkfc	Sum_L_wrkfor	Sum_L_empl	Sum_L_unem
100	3	8715762.0000	5457438.0000	243734.0000	4376054.0000	4057624.0000	255469.0000
101	6	13206943.0000	8585406.0000	285346.0000	7139529.0000	5637962.0000	444939.0000
102	3	37602286.0000	24160589.0000	662276.0000	18956272.0000	7673948.0000	199673.0000
103	5	14035371.0000	9071427.0000	280106.0000	7410910.0000	5819930.0000	362113.0000
104	4	8104980.0000	4963220.0000	173749.0000	3894891.0000	3576664.0000	260262.0000
132	1	3685296.0000	2320796.0000	75743.0000	1718145.0000	1563960.0000	124354.0000
133	7	41022470.0000	25608264.0000	829848.0000	20371660.0000	3763991.0000	180159.0000
134	1	2350725.0000	1425891.0000	51944.0000	1077151.0000	994289.0000	72079.0000

7.1.3 Linking the Database with TAZ_ID and Attaching Attribute Data to the Map

1. These new databases are aggregated in Microsoft Excel to form total_data_taz.dbf. This is then opened in ArcView, and the previous summarization process is run again in order to confirm the aggregation by TAZ_ID.

2. In ArcView, tazlatlong.shp is opened and the database total_data_taz.dbf is linked to it by the common variable, TAZ_ID. Now the tazlatlong.shp has socioeconomic attribute data attached to it. The process is also represented by a flow chart in Appendix C. The resultant output is as follows:



7.2 Attributes of Modal and IntermodaleNworks

7.2.1 Highway Network

Transport of commodities on the highway network, by way of truck transport, has a certain associated charge per ton-mile assessed to the shipper. This cost of transportation varies by commodity, often dictated by time-sensitivity and packaging requirements. For this modeling process, cost of truck transport on a highway link is assumed to be a function of distance.

7.2.2 Railroad Network

Shippers transporting commodities on the railway network are assessed a certain charge per ton-mile. Like truck transport rates, this cost of transportation varies by commodity, and is often affected by bulk quantity, time-sensitivity, and packaging requirements. Cost of rail transport on this network representation is also assumed to be a function of distance. This figure, like truck transport rates, will vary by commodity, shipment size, and car type.

7.2.3 Intermodal Transfer Definition

The transportation system represented in this study is multimodal, reflecting the behavior of various interactions between rail and truck modes. Intermodal transfers between rail and truck will occur only at specific locations in the system. These locations, operating as intermodal terminals, have the equipment and facilities available to efficiently transfer shipments between these two modes. Rail intermodality includes a broad range of services: trailer-on-flatcar (TOFC), also commonly referred to as "piggyback"; container-on-flatcar (COFC); double-stack train (DST); and carless technologies. For the purposes of this study, an intermodal movement of any kind may occur at a designated intermodal transfer.

Intermodal terminals for this transportation network are located from the GIS TOFC/COFC coverage in the BTS NTAD. There are 367 locations in the original table. Those locations that are specifically noted in the data are being operated by one of the eight railroad operators that provided a smaller list. Next, this list is narrowed further to one transfer point per operator in each TAZ. The only exception to this selection criterion is Memphis, Tennessee, a known high-volume intermodal transfer location for the selected four Class I railroad operators. All intermodal terminals within Iowa are included in the NTAD database. This elimination process left 55 intermodal terminals remaining.

The two networks of rail and highway are joined only at these intermodal connection points. For each intermodal facility, the nearest rail line coinciding with that intermodal operator is located and spliced. Intermodal connectors are then drawn from this rail line and connected to the nearest primary highway. These intermodal connectors are drawn and added in the railroad network, constructed separately from the highway network. However, to make these connections, rail lines and highway links are spliced separately (alternating between editable layers). The individual network, after all splicing and intermodal connections are completed, is then run through ID_NOD.MBX to obtain nodes and coordinates (*12*).

7.2.4 Intermodal Transfer Attributes

Costs of transfers are incurred when carriers transfer shipments through intermodal terminals. The costs will vary by commodity and type of intermodal movement.

These intermodal transfers are coded as turn penalties for the purposes of modeling. Movements from a rail facility, through an intermodal facility, to a highway route (and vice-versa), are penalized a specific dollar/ton value. This table exists as IMTRNSFR.TAB, a MapInfo table of the node combinations that comprise the penalized movement. The transfer nodes included in this table should be located on the multimodal (rail/highway) network to investigate how intermodal transfers are depicted. Once all rail-intermodal points are identified and entered in a table, SQL

REFERENCES

1. Walter, C. K., C. P. Baumel, and R. G. Mahayni. *Multimodal Investment Analysis Methodology; Phase I: The Conceptual Model.* Center for Transportation Research and Education, Ames, Iowa, Dec. 1998.

2. *Guidebook on Statewide Travel Forecasting.* Federal Highway Administration, U.S. Department of Transportation, March 1999, p. 116.

3. *What Distinguishes the REMI Model (a)*. Regional Economic Models, Inc., Aug. 1998. http://www.remi.com/html/closeup.html.

4. *What Distinguishes the REMI Model (b)*. Regional Economic Models, Inc., Aug. 1998, http://www.remi.com/html/apart.html.

5. Kanafani, A. K. *Transportation Demand Analysis.* McGraw Hill, Princeton, N.J., 1983.

6. *Iowa Rail Route Alternatives Analysis.* Transportation Economics and Management Systems, Inc., June 1998.

7. Ralston, B. A, G. Tharakan, and C. Liu. A Spatial Decision Support System for Transportation Policy Analysis in Bangladesh. *Journal of Transport Geography* Vol. 2, No. 2, 1994, pp. 101–110.

8. Gervais, J.-P., M. J. McVey, and C. P. Baumel. *Quantities of Corn and Soybeans Requiring Transportation Out of Iowa Counties.* Extension Office, Iowa State University, Ames, Iowa, 1996.

9. http://www.asa-europe.org/stats/genl.htm.

10. Hanson, S. D., C. A. Hamlett, G. Pautsch, and C. P. Baumel. Vehicle Travel Costs and Paved, Granular, and Earth Surfaced County Roads. *Proceedings of the 26th Annual Meeting of the Transportation Research Forum*, Vol. 26, No. 1, 1985.

11. Gervais, J.-P., and C. P. Baumel. The Iowa Grain Flow Survey: Where and How Iowa Grain Producers Ship Corn and Soybeans. *Journal of the Transportation Research Forum*, Vol. 37, No. 1, 1998, p. 17.

12. Souleyrette, R., and D. T. Pressig. *The Statewide Transportation Planning Model and Methodology Development Program: Phase II.* Center for Transportation Research and Education, Ames, Iowa, May 1998.

13. *Gander: The Untold Story.* Canadian Aviation Safety Board. http://www.sandford.org/gandercrash/ investigations.

14. Commercial airline pilot. Private communications, Nov. 1999.

15. Sidhu, S. Standard Setting Processes and Regulations for Environmental Contaminants in Drinking Water: State Versus Federal Needs and Viewpoints. *Regulatory Toxicology and Pharmacology* 13(3):293–308.

16. http://www.censuscd.com/cdmaps/what_f.htm.

17. http://www.bts.gov/ntda/npts/desc.html.

18. http://www.bts.gov/ntda/cfs.

19. http://www.bts.gov/ntda/cfs/desc.html.

20. http://www.bts.gov/ntda/cfs/desc.html.

21. http://www.bts.gov/gis/ntatlas/index.html.

APPENDIX A

TRANSPORTATION COST ESTIMATION METHOD

Source: Hanson, S. D., C. A. Hamlett, G. Pautsch, and C. P. Baumel. Vehicle Travel Costs and Paved, Granular, and Earth Surfaced County Roads. *Proceedings of the 26th Annual Meeting of the Transportation Research Forum*, Vol. 26, No. 1, 1985.

Fuel Costs for Vehicle Type *i*

$F_i = FP_i / FC_i$

where

F_i = fuel cost in cents per mile
FP_i = fuel price in cents per gallon
FC_i = fuel consumption in miles per gallon = S_i / G_i

where

S_i = speed in miles per hour
G_i = fuel consumption in gallons per hour

G_i is obtained by regressing fuel consumption in gallons per hour on EL_i,

where

$EL_i = V_i + (D_i * S_i) / 375$

where

V_i = percent of engine load
D_i = the draft of each vehicle = $C_i * A_i$

where

C_i = adjustment coefficient to convert the weight of equipment being pulled
A_i = weight of the equipment being pulled

Oil Costs for Vehicle Type *i*

$O_i = OP_i * OC_i$

where

O_i = oil cost in cents per mile
OP_i = oil price for each vehicle
OC_i = oil consumption in quarts per mile = OM_i / S_i

where

OM_i is oil consumption in gallons per hour = $0.00573 + 0.00021 * H_i$

where

H_i = engine horsepower for each vehicle
S_i = speed in miles per hour

Tire Costs for Vehicle Type *i*

$$Ti = \sum_{k} (N_{ik} * TP_{ik}) / L_{ik}$$

where

T_i = tire cost in cents per mile
k = type of tire, such as front, rear, trailer tires
N_{ik} = number of the tire type k on each vehicle type
TP_{ik} = price of tire type k for each vehicle type
L_{ik} = expected life in miles of tire type $k = M_{ik} * S_i$

where

M_{ik} = expected life in hours of tire type k
S_i = speed in miles per hour

Maintenance Cost for Vehicle Type *i*

$$MC_i = R_i / AM_i$$

where

MC_i = maintenance and repair cost in cents per mile
R_i = average annual maintenance and repair cost in cents
AM_i = average annual miles driven by vehicle type i

R_i = total lifetime repairs in cents = $0.0128 (VP_i) * (Q_i/1000)^{2.033}$
AM_i = total lifetime miles of each vehicle = $Q_i * S_i$

where

VP_i = list price of each vehicle
Q_i = estimated life in hours for each vehicle
S_i = speed in miles per hour

Travel Time Cost

$$TT_i = (NA_i * W_i) / S_i$$

where

TT_i = travel time cost in cents per mile
NA_i = the average number of adults in vehicle type i
W_i = the estimated value of adults' time in cents per hour
S_i = the speed in miles per hour

APPENDIX B

MODEL DATA REQUIREMENTS AND SOURCES

Passenger Model

MODEL DATA REQUIREMENTS | **DATA SOURCES**

Trip Generation

$$E_{ip} = A_{ip} + \alpha_{ip}P_i + \beta_{ip}Y_i + \gamma_{ip}W_i + \delta\Sigma Z_i$$

MODEL DATA REQUIREMENTS	DATA SOURCES
A_{ip} = Intrinsic qualitative factor of zone *i* →	Co-efficient to be determined by regression
P_i = population density for zone *i* total population/area-GIS tool-to calculate →	CensusCD+Maps
Y_i = Per capita personal income →	CensusCD+Maps
W_i = Percentage of workers (employed) →	CensusCD+Maps
Z_i = Dummy variable, $Z_0 = 0$ car, $Z_1 = 1–2$ cars, $Z_2 = 2.+$ cars →	CensusCD+Maps
OR (No. of vehicles registered in county/No. of households)	
δ = (Number of persons above 16)/Population →	CensusCD+Maps

A_{ip}, α_{ip}, β_{ip}, γ, δ are co-efficients to be determined.

$$E_{jp} = A_{jp} + \varepsilon S_j + \zeta E_j$$

MODEL DATA REQUIREMENTS	DATA SOURCES
A_{jp} = Intrinsic qualitative factor of zone j (pull factor) for trip purpose *p*	
εS_j = Retail sales ($) →	http://129.186.32.200/data/retail/ (Iowa)
ζE_j = Number of employees of zone *j* →	CensusCD+Maps

Passenger Model

MODEL DATA REQUIREMENTS	**DATA SOURCES**
Trip Distribution	
$X^t_{ijkp} = F(X^t_{ijp}, F_{ijp})$	
X^t_{ijp} = Total demand from origin *i* to destination *j*, at time *t*, for trip purpose $p = (E_{ip}E_{jp}) / I_{ijp}$	
F_{ijkp} = Friction factor	
$E_{ip} = A_{ip} + \alpha_{ip} P_i + \beta_{ip} Y_i + \gamma_{ip} W_i + \delta \Sigma Z_i$ →	Calculated above
$E_{jp} = A_{jp} + \varepsilon S_j + \zeta E_j$ →	Calculated above
I_{ijp} = Impedance (Distance between *i* and *j*) for trip purpose *p* →	Network Links Data - Network.tab
$F_{ijp} = f_{ijp} / \Sigma f_{ijp}$ = Friction factor between origin *i* and destination *j*, for trip purpose *p* = f1 Distance + f2Time + f3Cost →	Distance - Network Links data Speed = distance/speed - Network Links data Travel time (excluding egress and access time) = 35%(air), 30%–50% (rail), 100% (auto) Ref: http://www.fra.dot.gov/doc/hsgt/cfs/indes.htm
$X^t_{ijkp} = X^t_{ijp} F_{ijp}$	

Passenger Model

MODEL DATA REQUIREMENTS

DATA SOURCES

Modal Choice

$M_{ijkp} = f(U_{ijkp})$

$M_{ijmp} = (e^{U_{ijmp}}/\rho) / (\Sigma e^{U_{ijmp}}/\rho)$ → Can be calculated after the generalized cost function is determined for all modes

U_{ijkp} = Generalized cost function = $GC_{ijmp} = TT_{ijm} + TC_{ijmp} / VOT_{mp} + (VOF_{mp} \text{ x } OH) / (VOT_{mp}\, x\, F_{ijm}\, x\, C_{ijm}) + VOR_{mp} \exp(-OTP_{ijm}) / VOT_{mp}$

TT_{ijm} = Travel time between zones *i* and *j* for mode *m*

TC_{ijmp} = Travel cost between zones *i* and *j* for mode *m* and trip purpose *p*

VOT_{mp} = Value of Time for mode *m* and trip purpose *p*

VOF_{mp} = Value of Frequency for mode *m* and trip purpose *p*

OH = Operating hours per week

F_{ijm} = Frequency in departures per week between zones *i* and *j* for mode *m*

C_{ijm} = Convenience factor of schedule times for travel between zones *i* and *j* for mode *m*

VOR_{mp} = Value of Reliability for mode *m* and trip purpose *p*

OTP_{ijm} = On-time performance for travel between zones *i* and *j* for mode *m*

→ Survey data required, as in TEMS Report

ρ = Nesting co-efficient

Freight Model—Agricultural Products

MODEL DATA REQUIREMENTS

Amount of Crops for Off-Farm Use

1. Estimation of corn and soybean production in the state

2. Subtract the farm usage of corn and soybean from the production estimate; farm usage is estimated in the following:

   i. Estimate the amount of livestock and poultry production

   ii. Estimate the feeding rate of livestock and poultry

DATA SOURCES

http://www.nass.usda.gov/ia/. At this site, data are available by county level for the year 1995, 1996 and 1997. For previous years, *Iowa Agricultural Statistics,* published by USDA National Agricultural Statistics Service and Iowa Farm Bureau provides this in similar formation.

Data are available for census years. Data for non-Census years are estimated based on data in Census years.

Estimated Annual Feeding Amount

Livestock class	Bushels of corn consumed per year per head
Milk cows	102.00
Beef cows	4.00
Grain-fed cattle	55.30
Hog marketed	12.60
Confinement swine	
Finishers (per marketing)	8.60
Sow-units (inventory)	27.90
Nursery (per marketing)	0.85
Sheep and lambs	6.80
Poultry	
Broilers (per marketing)	0.11
Layers (inventory)	0.93
Turkeys (per marketing)	0.89

Source: Gervais, J.-P., M. J. McVey, and P. C. Baumel. *Quantities of Corn and Soybeans Requiring Transportation Out of Iowa Counties.* Iowa State University, July 1996.

Freight Model—Agricultural Products

MODEL DATA REQUIREMENTS	DATA SOURCES
iii. Estimate the amount of corn and soybeans fed to livestock and poultry →	Multiplying each livestock and poultry estimate and the corresponding feeding rate outlined explained above. Soybeans are already processed before they are used for feed. Therefore, to estimate the off-farm use of soybeans, feeding amount is not taken into account.
iv. Estimate the amount of corn and soybeans kept for seed →	Corn: negligible. Soybeans: 1 bushel per acre
2. Determine the amount of corn and soybean available for off-farm usage Corn →	Calculated above

$$CS_{it} = CP_{i(t-1)} - [\ L_{kit}\ FR_{kit} - OP_{i(t-1)}\ ]$$

where

CS_{it} = corn sales in county i, year t

$CP_{i(t-1)}$ = corn production in county i, year $t-1$

L_{kit} = number of head in the kth class of livestock in county i, year t

FR_{kit} = feeding rate for each class of livestock in county i, year t

$OP_{i(t-1)}$ = oat production in county i, year t

Freight Model—Agricultural Products

MODEL DATA REQUIREMENTS

Soybean →

$SSit = SPit - SACit (SR)$

where

SSit = soybean sales in county *i*, year *t*

SPit = soybean production in county *i*, year *t*

SACit = acres of soybeans planted in county *i*, year *t*

SR = seeding rate for soybeans (assumed to be 1 bushel per acre)

Estimation of the Distribution of Crops →

Maximization of margin, by using the following equations:

Margin (farm) = elevator bid price – transportation cost (i)

Margin (elevator) = market bid price – transportation cost – elevator bid price (ii)

Notes: Elevator bid price, market bid price, and transportation costs are per bushel;

GAMS program used to estimate grain flow in Iowa.

DATA SOURCES

Calculated above

Elevator bid price per bushel

- Data Transmission Network (DTN)
- Elevator bid prices are not available for all the elevators-need to be estimated by:

elevator bid price = market bid price – transportation cost – margin.

Market bid price per bushel

- Industry sources and are not readily available.

Transportation cost per bushel (farm to elevator)

Vehicle Type	Variable cost in cents per bushel mile
Tractor-wagon	
One-wagon	0.38
Two-wagon	0.22
Farmers owned truck	
Single-axle	0.143
Tandem-axle	0.107
Semi	0.074
Commercial semis	0.111

Transportation Cost (elevator to market)

- From elevators to markets, possible transportation modes are semis and rails, different for corn and soybean.
- Through direct contact to the rail companies.
- Web-sites.

Freight Model—Manufactured Products

MODEL DATA REQUIREMENTS	DATA SOURCES
Trip Generation	
County origin tons = BEA origin tons * County employment/BEA employment County destination tons = BEA destination tons * County consumption/BEA consumption	• Commodity Flow Survey (1993) • The Statewide Transportation Planning Model and Methodology Development Program Phase II • CensusCD+Maps
Trip Distribution	
Gravity Model used: $V_{ij} = (P_i\ A_j\ F_{ij}\ K_{ij}) / \Sigma A_j\ F_{ij}\ K_{ij}$	
V_{ij} = Volume of freight from zone *i* to zone *j*	Calculated
P_i = Freight volume produced at zone *i*	Reebie92.tab-conversion needed
A_j = Freight volume attracted to zone *j*	Reebie92.tab-conversion needed
F_{ij} = Trip impedance factor from zone *i* to zone *j* (using travel time)	Food and Kindred Products (SIC 20) $F_{ij} = e^{-0.0048*Dij}$ Machinery, except electrical (SIC 35) $F_{ij} = e^{-0.0023*Dij}$ The Statewide Transportation Planning Model and Methodology Development Program Phase II
K_{ij} = Interzonal adjustment factor from zone i to zone j (using length of haul)	Can be considered 0 in Iowa

Freight Model—Manufactured Products

MODEL DATA REQUIREMENTS	**DATA SOURCES**
Modal Choice U_{ijkm} = F (Cost, Time)	
C_{ijkm} = Cost from *i* to *j* for commodity *k* by mode *m* $= L * VC * CFC * MFC * LCM * SCM + I_i (CFC * MFC * LCM * SCM)$	Calculated from the data below
L = length of link	The Statewide Transportation Planning Model and Methodology Development Program Phase II
VC = variable cost ($ per ton-mile)	Air - http://www.bts.gov/NTL/data/domfares4.pdf Auto - http://www.bts.gov/NTL/data/nationf.pdf
CFC = Fixed facilities cost ($ per ton), due to commodity characteristics	$/ton
MFC = Fixed facilities cost ($ per ton)	$/ton
LCM = link's unique cost multiplier reflecting link's state of repair	Nominally 1
SCM = mode's seasonality cost	Nominally 1
I_i = Dummy variable, I = 0, no intermodal transfer; I = 1, intermodal transfer	TOFC/COFC coverage in BTS NTAD

Freight Model—Manufactured Products

MODEL DATA REQUIREMENTS	DATA SOURCES

$$T_{ijkm} = \text{Time taken to go from } i \text{ to } j\text{, for commodity } k\text{, by mode } m = (L / S) * MFT * CFT * LTM * STM + I_i (MFT * CFT * LCM * STM)$$

L = length of link S = speed (mph)	Network.tab, Rail.tab
MFT = Loading or transfer time	Nominally 1
CFT = Time due to the commodity characteristics	Nominally 1
LTM = Link's unique time multiplier, reflecting link's state of repair	Nominally 1
STM = mode's seasonality time multiplier	Nominally 1

$$U_{ijkm} = B_{1k}C_{ijkm} + B_{2k}T_{ijkm}V_k + B_{3k}d_1 + B_{4k}\, d_2$$

V_k = value of commodity *k*	To be determined, expected negative
B_{1k} = weight	To be determined, expected negative
B_{2k} = weight	To be determined, expected negative
B_{3k} = weight	To be determined, either sign
B_{4k} = weight	To be determined, either sign

Freight Model (Manufactured Goods)

MODEL DATA REQUIREMENTS | **DATA SOURCES**

d_1 = dummy variable (1 if road, 0 otherwise)

d_2 = dummy variable (1 if rail, 0 otherwise)

The modal share (the probability of using mode *m* from zone *i* to zone *j* by commodity *k*) is

$P_{ijkm} = e^{U_{ijmp}} / \Sigma\, e^{U_{ijmp}}$ → Calculated from data above with the help of TransCAD

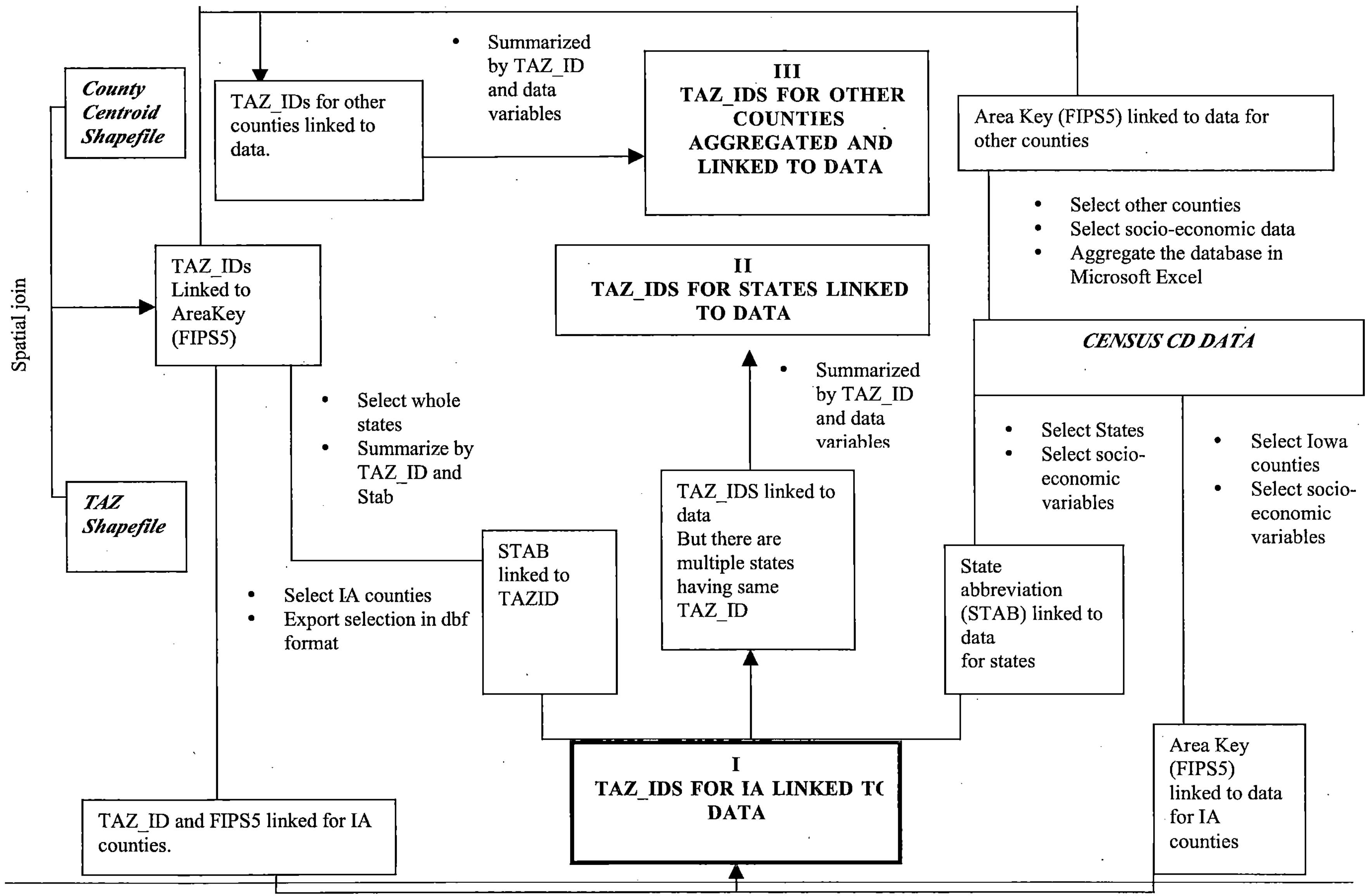
Cost and Other Data Needed and Available

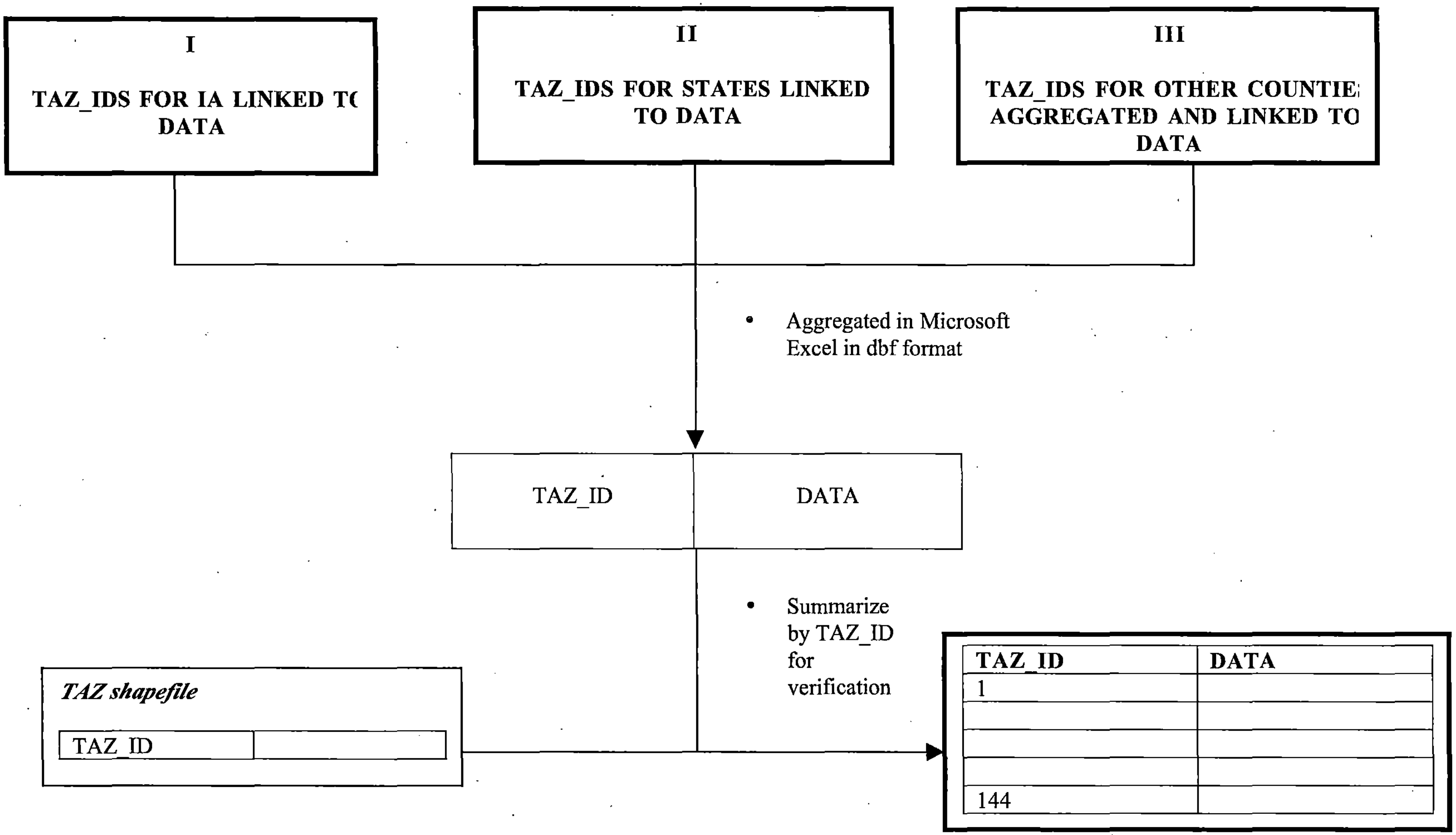
Variable	Motor Freight	Railroad	Air Freight	Water	Page Ref.
Capacity (tons/vehicle)	25	90	100	1,500 & up	143, 170, 226
Revenue ($/ton-mi.)	0.2438	0.0266	0.4634	0.0075	226
Speed (m.p.h.)	45	20	453	7	141, 184, 204, 226–227
Modal share, % of ton-mi.	25.7	37.4	0.3	16.2	14
Ave. length of haul (miles)	391	650	1,397	441-1,974	201, 225

Source: Coyle, J. J.; E. J. Bardi, and R. A. Novack, *Transportation*, 4th ed. (St. Paul: West Publishing Company, 1994).

APPENDIX C

TRAFFIC ANALYSIS ZONE STRUCTURES


County Centroid Shapefile
TAZ_IDs for other counties linked to data.
Summarized by TAZ_ID and data variables
III
TAZ_IDS FOR OTHER COUNTIES AGGREGATED AND LINKED TO DATA
Area Key (FIPS5) linked to data for other counties
Select other counties
Select socio-economic data
Aggregate the database in Microsoft Excel
Spatial join
TAZ_IDs Linked to AreaKey (FIPS5)
II
TAZ_IDS FOR STATES LINKED TO DATA
CENSUS CD DATA
Summarized by TAZ_ID and data variables
Select whole states
Summarize by TAZ_ID and Stab
Select States
Select socio-economic variables
Select Iowa counties
Select socio-economic variables
TAZ Shapefile
TAZ_IDS linked to data
But there are multiple states having same TAZ_ID
STAB linked to TAZID
State abbreviation (STAB) linked to data for states
Select IA counties
Export selection in dbf format
I
TAZ_IDS FOR IA LINKED TO DATA
Area Key (FIPS5) linked to data for IA counties
TAZ_ID and FIPS5 linked for IA counties.


I
TAZ_IDS FOR IA LINKED T(
DATA
II
TAZ_IDS FOR STATES LINKED
TO DATA
III
TAZ_IDS FOR OTHER COUNTIE
AGGREGATED AND LINKED TO
DATA
Aggregated in Microsoft
Excel in dbf format
TAZ_ID
DATA
Summarize
by TAZ_ID
for
verification
TAZ shapefile
TAZ_ID
TAZ_ID
DATA
1
144

APPENDIX D

DATA TABLE STRUCTURES

TAZs with Sample Attribute Data

TAZ.* File Structure

Column Name	Type	Description
FIPS	Small Integer	State FIPS code of TAZ (or Reebie region)
BEA	Small Integer	BEA code of TAZ (or Reebie region)
TAZ_ID	Integer	TAZ code (1-99 for Iowa counties)
emp_ratio201	Float	County employ. / BEA employ., for SIC 201
emp_ratio352	Float	County employ. / BEA employ. , for SIC 352
pop_ratio	Float	County population / BEA population
Farm_ratio	Float	County farmland / BEA farmland
Population	Integer	County population (Iowa counties only)
pop_bea	Integer	BEA population
Co_farm_land	Integer	County farmland (Iowa counties only)
BEA_farm	Integer	BEA farmland
SIC10 through SIC390	Integer	Industry employment (Iowa counties only)
BEA_201	Integer	Industry employment in BEA for SIC 201
BEA_352	Integer	Industry employment in BEA for SIC 352

Arcview shapefile (*.shp) and *.dbf formats, acceptable for TransCAD.

Networks

Network.tab Table Structure

Column Name	Type
RAIL_CLASS	Small Integer
SPEED_LIMIT	Small Integer
A_NODE	Integer
B_NODE	Integer
ASSIGN_GROUP	Small Integer
DISTANCE	Integer
MI_DISTANCE	Float
FIELD_OPTION	Character(1)
FIELD1	Integer
FIELD2	Integer
DIRECTION_CODE	Small Integer
LINK_GROUP1	Small Integer
LINK_GROUP2	Small Integer
LINK_GROUP3	Small Integer
CAPACITY	Integer
CAPACITY2	Integer
BA_OPTION	Character (1)
A_X	Decimal (13,2)
A_Y	Decimal (13,2)
B_X	Decimal (13,2)
B_Y	Decimal (13,2)
LINK_ID	Integer
OWNER	Character (5)
TYPE	Character (20)
COMMENTS	Character (40)

Nodes.tab Table Structure

Column Name	Type
N	Character (1)
NODE #	Integer
XCOORD	Decimal (13,2)
YCOORD	Decimal (13,2)

Intermodal

Imtrnsfr.tab Table Structure

Column Name	Type
FROM_RAIL	Integer
INTERMODAL	Integer
TO_TRUCK	Integer
PENALTY	Integer
OWNER	Character (5)

Intrlnks.tab Table Structure

Column Name	Type
RAIL_CLASS	Small Integer
SPEED_LIMIT	Small Integer
A_NODE	Integer
B_NODE	Integer
ASSIGN_GROUP	Small Integer
DISTANCE	Integer
MI_DISTANCE	Float
FIELD_OPTION	Character(1)
FIELD1	Integer
FIELD2	Integer
DIRECTION_CODE	Small Integer
LINK_GROUP1	Small Integer
LINK_GROUP2	Small Integer
LINK_GROUP3	Small Integer
CAPACITY	Integer
CAPACITY2	Integer
BA_OPTION	Character (1)
A_X	Decimal (13,2)
A_Y	Decimal (13,2)
B_X	Decimal (13,2)
B_Y	Decimal (13,2)
LINK_ID	Integer
OWNER	Character (5)
TYPE	Character (20)
COMMENTS	Character (40)

Intrmdl.tab Table Structure

Column Name	Type
OWNER	Character (10)
POINTID	Integer
FEATUREID	Character (10)
LONGITUDE	Integer
LATITUDE	Integer
DESCRIP	Character (35)
STFIPS	Integer

Intrnods.tab Table Structure

Column Name	Type
NODE#	Integer
XCOORD	Decimal (13,2)
YCOORD	Decimal (13,2)

Intrnods.tab Table Structure

Column Name	Type
FROM_RAIL	Integer
INTERMODAL	Integer
TO_TRUCK	Integer
PENALTY	Integer
OWNER	Character (5)

Rail

Cntrrail.tab Table Structure

Column Name	Type
TO	Integer
THRU	Integer
FROM	Integer
PENALTY	Integer
OWNER	Character (5)

Cntrtran.tab Table Structure

Column Name	Type
TO	Integer
THRU	Integer
FROM	Integer
PENALTY	Integer
OWNER	Character (5)

No_rail.tab Table Structure

Column Name	Type
TO_NODE	Integer
TRANSFERS	Integer
FROM_NODE	Integer
PENALTY	Integer
OWNERS	Character (12)

No_trk.tab Table Structure

Column Name	Type
TO_NODE	Integer
TRANSFERS	Integer
FROM_NODE	Integer
PENALTY	Integer
OWNERS	Character (12)

Op_notrk.tab Table Structure

Column Name	Type
TO_NODE	Integer
TRANSFERS	Integer
FROM_NODE	Integer
PENALTY	Integer
OWNERS	Character (12)

Rail.tab Table Structure

Column Name	Type
RAIL_CLASS	Small Integer
SPEED_LIMIT	Small Integer
A_NODE	Integer
B_NODE	Integer
ASSIGN_GROUP	Small Integer
DISTANCE	Integer
MI_DISTANCE	Float
FIELD_OPTION	Character(1)
FIELD1	Integer
FIELD2	Integer
DIRECTION_CODE	Small Integer
LINK_GROUP1	Small Integer
LINK_GROUP2	Small Integer
LINK_GROUP3	Small Integer
CAPACITY	Integer
CAPACITY2	Integer
BA_OPTION	Character (1)
A_X	Decimal (13,2)
A_Y	Decimal (13,2)
B_X	Decimal (13,2)
B_Y	Decimal (13,2)
LINK_ID	Integer
OWNER	Character (5)
TYPE	Character (20)
COMMENTS	Character (40)

Railn.tab Table Structure

Column Name	Type
NODE#	Integer
XCOORD	Decimal (13,2)
YCOORD	Decimal (13,2)

Railx.tab Table Structure

Column Name	Type
RAIL_CLASS	Small Integer
SPEED_LIMIT	Small Integer
A_NODE	Integer
B_NODE	Integer
ASSIGN_GROUP	Small Integer
DISTANCE	Integer
MI_DISTANCE	Float
FIELD_OPTION	Character(1)
FIELD1	Integer
FIELD2	Integer
DIRECTION_CODE	Small Integer
LINK_GROUP1	Small Integer
LINK_GROUP2	Small Integer
LINK_GROUP3	Small Integer
CAPACITY	Integer
CAPACITY2	Integer
BA_OPTION	Character (1)
A_X	Decimal (13,2)
A_Y	Decimal (13,2)
B_X	Decimal (13,2)
B_Y	Decimal (13,2)
LINK_ID	Integer
OWNER	Character (5)
TYPE	Character (20)
COMMENTS	Character (40)

Transfr.tab Table Structure

Column Name	Type
NODE #	Integer
LOCATION	Character (40)

Transfrs.tab Table Structure

Column Name	Type
TO_NODE	Integer
TRANSFERS	Integer
FROM_NODE	Integer

Column Name	Type
PENALTY	Integer
OWNERS	Character (12)

Trnslnks.tab Table Structure

Column Name	Type
FROM_NODE	Integer
TRANSFER_NODE	Integer
LINK_ID	Integer
OWNER	Character (5)

Road

Road.tab Table Structure

Column Name	Type
A_NODE	Integer
B_NODE	Integer
ASSIGN_GROUP	Small Integer
DISTANCE	Integer
FIELD_OPTION	Character(1)
FIELD1	Integer
FIELD2	Integer
DIRECTION_CODE	Small Integer
LINK_GROUP1	Small Integer
LINK_GROUP2	Small Integer
LINK_GROUP3	Small Integer
CAPACITY	Integer
CAPACITY2	Integer
BA_OPTION	Character (1)
A_X	Decimal (13,2)
A_Y	Decimal (13,2)
B_X	Decimal (13,2)
B_Y	Decimal (13,2)
HIGHWAY	Character (30)
LINK_ID	Integer
OWNER	Character (5)
TYPE	Character (20)
COMMENTS	Character (40)

Roadn.tab Table Structure

Column Name	Type
NODE#	Integer
XCOORD	Decimal (13,2)
YCOORD	Decimal (13,2)

Roadx.tab Table Structure

Column Name	Type
RAIL_CLASS	Small Integer
SPEED_LIMIT	Small Integer
A_NODE	Integer
B_NODE	Integer
ASSIGN_GROUP	Small Integer
DISTANCE	Integer
MI_DISTANCE	Float
FIELD_OPTION	Character (1)
FIELD1	Integer
FIELD2	Integer
DIRECTION_CODE	Small Integer
LINK_GROUP1	Small Integer
LINK_GROUP2	Small Integer
LINK_GROUP3	Small Integer
CAPACITY	Integer
CAPACITY2	Integer
BA_OPTION	Character (1)
A_X	Decimal (13,2)
A_Y	Decimal (13,2)
B_X	Decimal (13,2)
B_Y	Decimal (13,2)
LINK_ID	Integer
OWNER	Character (5)
TYPE	Character (20)
COMMENTS	Character (40)

R_cent.tab Table Structure

Column Name	Type
CENTROID	Integer
TO_NODE	Integer
THRU_NODE	Integer
PENALTY	Integer
OWNER	Character (5)

Cntrtruk.tab Table Structure

Column Name	Type
CENTROID	Integer
TO_NODE	Integer
THRU_NODE	Integer
PENALTY	Integer
OWNER	Character (5)

TAZ

Centroid.tab Table Structure

Column Name	Type
CENT_ID	Small Integer

###emp.tab Table Structure

Column Name	Type
BEA	Small Integer
_COL2	Float

Stations

Stations.tab File Structure

Column Name	Type
STATION	Character (4)
SURVEY_###	Float
OD_###	Float
GM_###	Float

REEBIE92.TAB File Structure

Column Name	Type	Description
ORIGSTATE	Small Integer	Origin State for shipment
ORIGBEA	Small Integer	Origin BEA for shipment
DESTSTATE	Small Integer	Destination State for shipment
DESTBEA	Small Integer	Destination BEA for shipment
COMMODITY	Small Integer	SIC Code, 3 digit
RAILCONTTON	Integer	Rail tons in container
RAILINTER	Integer	Rail tons by intermodal
HIRECONTTON	Integer	Truck tons by for-hire carrier in container
HIREBULKTON	Integer	Truck tons by for-hire carrier in bulk
LTLTON	Integer	Truck tons by LTL
PRIVCONTTON	Integer	Truck tons by private carrier in container
PRIVBULKTON	Integer	Truck tons by private carrier in bulk
AIRTON	Integer	Airborne freight tons
H2OCONTTON	Integer	Waterborne freight tons in container
H2OBULKTON	Integer	Waterborne freight tons in bulk
TOTVALUE	Integer	Estimated total value of all shipments in $
TOTWEIGHT	Integer	Estimated total weight of all shipments